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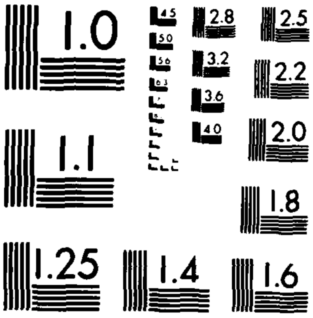
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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

DEVELOPMENT OF GRAPHICAL POLE-ZERO,
ROOT-LOCUS, BODE, NYQUIST, AND NICHOLS
RESPONSES USING THE OPTSYSX PROGRAM

by

Michael Henry Laptas

September 1984

Thesis Advisor: Daniel J. Collins

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The addition of the FORTRAN program OPTGRAPH gives the user the capability to obtain classical analysis (Pole-Zero Map, Root Locus, Bode, Nyquist, and Nichols) of transfer functions, calculated for a system designed with the OPTSYSX program. The OPTGRAPH program uses high resolution precision plotting software to provide the user with highly accurate frequency response plots.

This series of programs permits users to rapidly carry out simulation, analysis, and design of Optimal Systems Control problems in a totally interactive mode.

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Development of Graphical Pole-Zero, Root-Locus, Bode, Nyquist, and Nichols Responses using the OPTSYSX Program

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ABSTRACT

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This series of programs permits users to rapidly carry out simulation, analysis, and design of Optimal Systems Control problems in a totally interactive mode.

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SYMBOLS

A = State (Ns,Ns) or Output (No,No) Weighting Matrix

B = Control (Nc,Nc) Weighting Matrix

C = Control Gain Matrix (Nc,Ns)

D = Control (No,Nc) or Noise (No,Ng) Feedforward Matrix

F = Open-Loop Dynamics Matrix (Ns,Ns)

G = Control Distribution Matrix (Ns,Nc)

GAM = State Disturbance Distribution Matrix (Ns,Ng)

H = Measurement Scaling Matrix (No,Ns)

K = Estimator Gain Matrix (Ns,Nob)

Nc = Number of Ccntrols

Ng = Number of Process Noise Sources

Ns = Number of States

No = Number of Cbservations or Measurements

Q = White Process Noise Covariance Matrix (Ng,Ng)

R = White Meas. Noise Covariance Matrix (No,No)

S = Steady-State Covariance Matrix of Control (Nc,Nc)

u = Control Vector (Nc,1)

v = White Measurement Noise Vector (No,1), with Zero Mean and Covariance Matrix R

w = White Process Noise Vector (Ng,1), with Zero Mean and Covariance Matrix Q

w0 = Constant Disturbance Vector (Ng,1)

x = State Vector (Ns,1)

xdot = Derivative cf State Vector (Ns,1)

xe = Estimate of State Vector (Ns,1)

xedot = Derivative of Estimate of State Vector (Ns,1)

y = Output Vectcr (No,1)

z = Measurement Vector (No,1)

I. INTRODUCTION

The purpose of this thesis is to describe the modification and additions tc the existing FORTRAN program (OPTSYS) which is used in the study and application of Optimal Systems Ccntrol theory.

The OPtimal SYstems control program was originally developed by Hall [Ref. 1] to support his research in rotary-wing aircraft control systems. Later program modifications were made by Walker [Ref. 2] and Liu [Ref. 3] of Stanford University, and are designated OPTSYS 4 and OPTSYS 5 respectively. OPTSYS modifications made by Hoden [Ref. 4] were primarily devoted to creating a user-friendly interactive version (OPTSYSX) of the OPTSYS 4 program. The latest modifications by Diel [Ref. 5] allowed the user to save matrices for subsequent runs of the OPTSYSX program, and formed data file sets for the time response program OPTCALC.

The intent of this thesis work was to develop an interactive program to plot the Pole-Zero map, Root-Locus, Bode, Nyquist, and Nichols responses to the open loop, closed loop noise, and compensator transfer functions of a State Variable Control System which has been developed using OPTSYS Program. Mincr modifications to the OPTSYSX Program were necessary to ccnstruct a data file sets for plotting the Pole-Zero Map, and in calculations for the Root-Locus, Bode, Nyquist, and Nichols plots.

It is assumed that the user is familiar with the basic concepts cf Control Theory and Optimal Systems Design. The symbol/naming conventions of Bryson [Ref. 6]. are used in the discussion of program operations and descriptions of problems using the OPTSYS System.

An overview of the OPTSYSX Program capabilities and of modifications to the existing programs is presented first. This is followed by a description of the program (OPTGRAPH), which was developed tc plot the Pole-Zero Map and to perform calculations for the Root-Locus, Bode, Nyquist, and Nichols plots.

This work concludes with examples of various types of problems demonstrated in the interactive mode, including a copy of each terminal session with the final results. Complete program listings for the OPTSYS EXEC program, CPTSYSX program, and CPTGRAPH program are included in appendices A,B, and C respectively.

II. THE OPTSYSX COMPUTER PROGRAM

A. BACKGROUND

OPTSYSX is a double-precision, interactive FORTRAN program employing modern control theory analysis techniques. Its capabilities include the calculation of the open-loop eigensystem, and the stationary closed loop system; the synthesis of regulators and filters; along with power spectral density, and modal distribution computations. The modifications introduced to the OPTSYSX program by this thesis work do not affect the program's original capabilities.

B. OVERVIEW

OPTSYSX is an extremely large and complex program with over 3000 lines of code. To use the program in its small version (dimensioned for a 32 X 32 "F", "G", and "H" matrices), the user must extend his Virtual Machine (VM) memory capacity beyond the default VM memory capacity of 720 kilobytes to 1024 kilobytes.

Any significant increase in the OPTSYSX program size, with the the resulting requirement for additional memory capacity, would cause user difficulties. For this reason the task of obtaining the Pole-Zero maps, Root-Locus, and Bode, Nyquist, Nichols plots for the open loop, noise and compensator transfer functions was relegated to a separate program (OPTGRAPH). Three data files (OPTGROL DATA, OPTGRNO DATA, and OPTGRCM DATA), containing the open loop, noise, and compensator transfer functions, are formed by the OPTSYS program to be transfered to the OPTGRAPH program. The OPTSYS EXEC program provides an interface between the

OPTSYSX program, the time response programs (OPTCALC and OPTPLCT), and the OPTGRAPH program.

C. OPTSYSX MODIFICATIONS

CPTSYSX program modifications consist of the addition of write statements, three flags, and a short routine to interpret user inputs.

Write statements,to input data to the OPTGROL, CPTGRNO, and CPTGRCM DATA files were added to the main program, subroutine INNER, subroutine ZEROS, and subroutine POLES. System information consisting of number of states (Ns), number of controls (Nc), number of measurements (No), number of process noise scurces (Ng), type transfer function (ITFX), Markov Parameter (IE), and two flags to be used by the CPTSYS EXEC and the OPTGRAPH programs is inputed from the main program. The write statements added to the subroutine INNER, and subroutine POLES input the poles for the open locp and noise transfer functions, and compensator transfer function respectively. The zeros, the numerator order, the gain, and the input and output numbers for all three transfer functions are obtained from the subroutine ZEROS.

The first of the two flags, input with the system infcrmation from the main program to the three data files, serves as a marker for the CPTSYS EXEC to locate the correct data line for reading system inputs. The second flag, which is set by the routine tc interpret user inputs, serves as a signal for the OPTSYS EXEC to either load the OPTGRAPH program if any one of the three transfer functions was calculated by the OPTSYSX program, and abort loading the OPTGRAPH program if none of the three transfer functions were calculated. The third flag (ITFX) is an existing OPTSYSX program flag. The flag (ITFX) is passed from the subroutine TF to the subroutine ZEROS to identify the calculation cf either an open loop, noise, or compensator transfer function zeros.

The short routine added to the main program of OPTSYSX reads the flags ITF1, ITF2, ITF3, and IRET. The flag sent to the CPTGROL, OPTGRNO, or OPTGRCM DATA files is set to allow loading of transfer function data file to the CPTGRAPH program if the user selects either of the transfer function options number two (calculate poles, residues, and zeros - ITF1 = 1, ITF2 = 1, or ITF3 = 1) number three (calculate poles, and zeros - ITF1 = 2, ITF2 =2, or, ITF3 = 2) when calculating the open loop, noise, or compensator transfer functions. The selection of any other transfer function option will not calculate the transfer function zeros. The flag IRET is read to determine if the user desires to rerun a problem without exiting the OPTSYSX program. Should the user elect to rerun a problem without exiting OPTSYSX (IRET = 1), the three data files are set back to the beginning (REWIND) to accept the new problem system data.

D. OPTSYS EXEC MODIFICATIONS

The OPTSYS EXEC was written by Diel [Ref. 5] to interface between the OPTSYSX program and the time response programs OPTCALC and CPTPLOT. The modifications to the exec program were to add the option to select running the OPTGRAPH program to the exec menues and a short section to interface the OPTGRAPH program with the OPTSYSX program.

The added section to interface between the OPTSYSX and OPTGRAPH programs defined loader size (LDRTBLE), file definitions (FILEDEF), and text libraries (TXTLIB) for the CPTGRAPH program. The first line of the three data files is read to ensure that there has been at least one of the three transfer functions calculated by the OPTSYSX program prior to loading OPTGRAPH program.

The OPTSYS EXEC routine is also used to send plots to the VERSATEC plotter from the OPTPLOT program and the OPTGRAPH program.

III. THE OPGRAPH PROGRAM

A. PROGRAM OVERVIEW

OPTGRAPH is an interactive FORTRAN program which uses the transfer function poles and zeros calculated by OPTISYSX to calculate, tabulate, and plot the Pole-Zero Map, Bode, Nyquist, Nichols, and Root-Locus responses for either the open loop, closed loop noise, or compensator transfer functions.

1. Program Language

OPTGRAPH is programmed in FORTRAN following the conventions of the IBM System /360/370/ FORTRAN IV language. OPTGRAPH has been compiled and run under both FORTRAN IV (G1) and FORTRAN H (extended) compilers on the IBM 3033.

2. Graphics Package

This program uses the Display Integrated Software System and Plotting System Software (DISSPLA) developed and distributed by the Integrated Software Systems Corporation (ISSCC) of San Diego, California. The DISSPLA package is a library of FORTRAN subroutines using FORTRAN IV conventions.

3. Library Subroutines

OPTGRAPH uses the International Mathematical and Statistical Library (IMSL) subroutine ZRPOLY to calculate the roots of a polynomial equation. ZRPOLY is a double precision FORTRAN subroutine to which is input a polynomial with real coefficients (double precision) in terms of decreasing powers of the polynomial. The subroutine finds the roots of the polynomial and returns a double precision complex array containing the roots. ZRPOLY is capable of accepting polynomials greater than 0 order and less than 101 order.

4. Program Composition

CPTGRAPH has one main program and 24 subroutines. The main program and its subroutines may be divided into four basic categories:

1) File Data Input
2) Interactive Data Input
3) Plot Setup and Sequencing
4) Calculation

A brief and general description of the program and its subroutines will follow in subsequent sections.

B. GENERAL PROGRAM OPERATION

OPTGRAPH was written to satisfy two specific objectives. The first is to create a program to be used as a instructional tool for students taking controls related courses, and the second is as method to assist in the analysis of actual large order control system problems.

To accomplish these objectives the emphasis while writing this program was to make the program as user oriented as possible by attempting to eliminate ambiguities and providing features which would protect the user from inadvertent wrong entries. An effort was also made to minimize the Virtual Machine (VM) memory required to execute the program to facilitate the analysis of a large order system.

1. User Protection Features

Three basic methods were used to protect the user from an abnormal program termination in the case of an inadvertent wrong entry. The first was to construct the subroutines to display a summery of the user inputs and allowing changes prior to leaving the subroutine. For the case where the user input is expected to fall within a given range, the input is examined and the user is either allowed to continue for an input within the range or issued an error or warning and reasked the question for an input outside the range. The final method is used by the three subroutines which read the user input from the screen. The subroutines RDINT, RDREAL,and RDCHAR expect an integer input, real number input, and a logical "yes" or "no" respectively. In the event that a "null" line is inadvertently entered, the user is issued a warning and allowed another opportunity to enter the the correct input before abnormally terminating the program. The entry of two "null" lines also offers the user the option to to exit the OPTGRAPH program at other than normal program exit points. The subroutine RDCHAR also examines the input and issues a warning if the input is not either "yes" or "no".

2. Large Order System

The large order control problem being considered for analysis by the OPTSYSX and the OPTGRAPH programs is the X-29A aircraft longitudinal axis backup mode system. This system has a (98 X 98) "F" matrix , a (2 X 98) "H" matrix, and a (98 X 1) "G" matrix.

To accommodate this large order system the OPTGRAPH program was dimensioned to accept a system with a maximum of 99 states (Ns), 12 controls (Nc), 12 process noise sources (Ng), and 12 measurements (No). The Virtual Machine (VM) memory requirements for the program were minimized by the reuse of memory locations allocated for storage of calculated data after that data has been either tabulated or plotted. This method of memory reuse has allowed the OPTGRAPH program to be dimensioned to accommodate a large order system and still operate with less than the 1024 KILOBYTES VM memory required to run OPTSYSX in its small version.

C. SYSTEM/MODEL DESCRIPTION

The system equations used by the OPTSYSX program for the calculation of the transfer functions are of the state variable form. The system equations are:
system model

$$xdot = [F]*x + [G]*u + [GAM]*w \tag{3.1}$$

measurement equation

$$z = [H]*x + [D]*u + v \tag{3.2}$$

estimator equation

$$xedot = [F]*xe + [G]*u + [K]*(z - [H]*xe) \tag{3.3}$$

open loop transfer function

$$[H]*|s[I] - [F]|^{-1}*[G] \tag{3.4}$$

closed loop noise transfer function

$$[H]*|s[I] - [F]|^{-1}*[Gam] \tag{3.5}$$

compensator transfer function from measurement to input

$$[C]*(|s[I]-[F]+[G]*[C]+[K]*[H]|^{-1})*[K] \tag{3.6}$$

where
u = Control vector (Ns X 1)

w = White process noise vector (Ng X 1)
x = State vector (Ns X 1)
xdot = Derivative of the state vector (NS X 1)
y = Output vector (No X 1)
z = measurement vector (No X 1)

[C] = control gain matrix (Nc,Ns)
[D] = control feed-forward distribution matrix (Nc,Nc) of the control vector (u)
[F] = open-loop dynamics matrix (Ns,Ns) (System matrix or Plant matrix)
[G] = control distribution matrix (Ns,Nc)
[GAM] = state disturbance distribution matrix (Ns,Ng)
[H] = measurement distribution matrix (No,Ns)
[I] = identity matrix (Ns,Ns)

D. PROGRAM ORGANIZATION

1. Main Program

The main program presents a menu allowing the user to select for analysis either the open loop transfer function, the closed loop noise transfer function, the compensator transfer function, or exit the OPTGRAPH program. The data file for the selected transfer function is examined by the main program to ensure that the file contains the required transfer function data. Should the data file be incomplete the program gives the user a warning message indicating the nature of the missing data and allows the user tc select another option.

The main program menu:

```
                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
```

```
          1.  OPEN LOOP TRANSFER FUNCTION
          2.  NOISE TRANSFER FUNCTION
          3.  COMPENSATOR TRANSFER FUNCTION
          4.  EXIT OPTGRAPH
     ENTER OPTION NUMBER.
```

Data is read from the selected file by the main program and formed into three arrays and seven integer variables. The exchange of data between the main program and the subroutines, and between the subroutines is by the extensive use of labeled common statements. The data transfered through the subroutine call statements is limited primarily to flags, and constants. The program moves to its primary sequencing subroutine (GRAPH) upon the completion of file data entry.

2. Program Sequencing

The subroutine GRAPH first presents the user with a summary of the the transfer system received from the data file. The user is then asked which transfer function he desires to to analyze using the conventions of the OPTSYSX program describing the transfer functions by input number and output number. A menu is presented which allows the user to select graphical and/or tabular system response (Pole-Zero map, Root-locus, Bode, Nyquist, or Nichols), select another transfer function, or exit the OPTGRAPH program. Upon completion of a graphical and/or tabular response option, or change of transfer function option, the program returns to the GRAPH menu to allow the user to choose another option or exit to the main program.

Subroutine GRAPH data summary and menu:

```
                    OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS CONTAINS:
     1.  NUMBER OF STATES =                    4
     2.  NUMBER OF CCNTROLS (INPUTS) =       1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) =  1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


               OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST, AND/
OR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?

     OUTPUT # ?


               OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR DATA  FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME TRANSFER
         FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT OPTGRAPH
ENTER OPTICN NUMBER.
```

3. Graphic and/or Tabular System Response

The selection of a graphical and/or tabular system response option for an Pole-Zero map, Root-Locus, Bode, open loop Nyquist, or open loop Nichols calls the subroutines

PZERO, RTLO, BODE, NYQST, or NICHOL respectively. While the response of these subroutines is different, their organization is similar.

The subroutines PZERO, RTLO, BODE, NYQST, and NICHOL primarily act as sequencing and plot setup subroutines. The interactive questioring of the user for graphic/tabular response information and the system response calculation has been relegated to other subroutines. The subroutines PZERO, RTLO, BODE, NYQST, and NICHOL are divided into two major sections with the first being devoted to producing a graphical output and the second to producing a tabular output.

The user is presented a subroutine menu offering the option for graphic response, tabular response, or exiting the subroutine. The program moves to either the first section (graphic response), second section (tabular response) or back to the subroutine GRAPH menu depending on the option selection. The program returns to the subroutine menu upon completion of the of either the graphic response, or tabular response section, allowing the user to select another response option, or exit the subroutine.

Features that are common to the five subroutines will be described here and features that are unique to one of the subroutines will be described in the following section under the appropriate response heading.

For a graphic response, the user is given the choice of two printer options (TEK 618, or VERSATEC). With the selection of the TEK 618, the plot page size is defaulted to 11 inches by 8.5 inches, and the plot will be presented on the TEK 618 screen. The VERSATEC option gives the user the option to create up to a 21 inch by 21 inch plot (maximum for the VERSATEC printer) and causes a DISSPLA METAFILE to be created. A scaling subroutine (PSCALE) scales the plot heading, legend, etc. in proportion to the page width selected. The VERSATEC option offers the the advantage of a high quality print from the VERSATEC printer using the VERSATEC printer option in the OPTSYS EXEC. The creation of a DISSPLA METAFILE also gives the user (after he exits optsys) the opportunity to use printers other than the TEK 618 or VERSATEC. A major disadvantage with the VERSATEC option is that the user must exit the OPTGRAPH program before he can print a graphic system response. For this reason, it is recommended that the system response first be plotted on the TEK 618 prior to selecting the VERSATEC option.

For a tabular response,the user is presented a menu which gives him the choice of three devices (screen, printer, or disk) to send the tabular output. The user is asked if he desires to make any changes, after the tabular data has been calculated. If the answer is affirmative, he is presented a menu and allowed to make changes and rerun the tabular data routine.

Examples of these features are included in the following sections with the interactive examples for the system responses.

E. INTERACTIVE EXAMPIES

The open-loop, closed loop noise, and compensator transfer functions are are handled identically by the OPTGRAPH program, with the only difference being the program and graph headings identifying the transfer function type. The frequency response programs for the Bode, Nyquist, and Nichols responses use identical setup and tabular data routines.

A gocd overall representation of the OPTGRAPH program capabilities will be demonstrated by single interactive terminal session examples for the pole-zero, root locus, and bode responses using selected transfer functions. Tabular data examples will be provided for the Pole-Zero, Root Locus, and Bode responses, and graphic response examples will be provided the Pole-Zero, Root Locus, Bode, Nyquist, and Nichols responses.

F. CHARACTERISTIC EQUATION ANALYSIS

The subroutines PZERO and RTLO are similar in their basic formats. The pole and zero locations for the selected transfer function input and output numbers are read into two single dimension arrays. The extraneous zeros, calculated by the OPTSYSX program, are eliminated by comparing the zeros to the Markov parameter sent with the system information from the OPTSYSX program. For a graphical response, the user is asked to define the plot limits in terms of X-coordinates (real axis) and Y-coordinates (imaginary axis). Points for the plot which fall outside these limits will be ignored. System information (tranfer function input number, output number, and (DC) gain) is listed in the graph legend.

1. Pole-Zero Map

The subroutine PZERO converts the double precision numbers for pole and zero locations to single precision for compatibility with the with the Graphics Package and plots the poles and zeros within the plot limits defined by the user for the graphical response routine. For tabular data response the user is given system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, and the pole and zero locations.

2. Pole-Zero Map (Interactive Example)

The following example of a simplified open loop transfer function for an airplane with an autopilot in the longitudinal mode was obtained from [Ref. 7,p.315].

The aircraft system is represented by:

$$[D] = [0]$$

$$[F] = \begin{vmatrix} 0. & 1. & 0. & 0. \\ 0. & 0. & 1. & 0. \\ 0. & 0. & 0. & 1. \\ 0. & 16. & -12. & -3. \end{vmatrix}$$

$$[G] = \begin{vmatrix} 0. \\ 0. \\ 1. \\ -2. \end{vmatrix}$$

$$[GAM] = [0]$$

$$[H] = [\ 1. \quad 0. \quad 0. \quad 0.\ ]$$

a. Example of Graphic Response (Terminal Session)

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 19:40:17
EXECUTION BEGINS...


                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.   OPEN LOOP TRANSFER FUNCTION
     2.   NOISE TRANSFER FUNCTION
     3.   COMPENSATOR TRANSFER FUNCTION
     4.   EXIT OPTGRAPH
ENTER OPTION NUMBER.
1


               OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS
CONTAINS:
     1.   NUMBER OF STATES =                         4
     2.   NUMBER OF CONTROLS (INPUTS) =              1
     3.   NUMBER OF MEASUREMENTS (OUTPUTS) =         1
     4.   MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


               OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
AND? OR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?
1
     OUTPUT # ?
1


               OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.   POLE-ZERO MAP
```

```
          2.   ROOT-LOCUS
          3.   BODE
          4.   NYQUIST (POLAR PLOT)
          5.   NICHOLS
          6.   ANOTHER INPUT/OUTPUT COMBINATION (SAME
               TRANSFER FUNCTION)
          7.   ANOTHER TYPE TRANSFER FUNCTION /EXIT
               CPTGRAPH
     ENTER OPTION NUMBER.
     1


               POLE-ZERO MAP
     OPEN LOOP TRANSFER FUNCTION
     DO YOU DESIRE:
          1.   GRAPHICAL OUTPUT
          2.   TABULAR DATA
          3.   QUIT SUBROUTINE
     ENTER OPTION NUMBER.
     1


               POLE-ZERO MAP
     OPEN LOOP TRANSFER FUNCTION
     PLOTTER SELECTION AND PAGE SIZE
     (NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
      SELECTION OF TEK618)
          WHICH PLOTTER DO YOU DESIRE:
               1. TEK618
               2. VERSATEC
          CHOOSE OPTION 1 OR 2
     2
           PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                     INCHES)
               HEIGHT =
     6
```

```
          WIDTH =
8
PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM = ?
-15
          X MAXIMUM = ?
5
     Y AXIS (IMAGINARY AXIS)
          Y MINIMUM = ?
-5
          Y MAXIMUM = ?
5

PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM =   -15.00
          X MAXIMUM =     5.00
     Y AXIS (IMAGINARY AXIS)
           Y MINIMUM =    -5.00
           Y MAXIMUM =     5.00
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n

PLOT HEADING

     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3MAX )
          ENTER NUMBER OF LINES.
            (ENTER "0" FOR NO HEADING)
3
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLCWED
     LINE 1 IS:
aircraft with an autopilot in
```

```
     LINE 2 IS:
the longitudinal mode
     LINE 3 IS:
ref. 7; page 315

PLOT HEADING
     LINE 1 :     AIRCRAFT WITH AN AUTOPILOT IN
     LINE 2 :     THE LONGITUDINAL MODE
     LINE 3 :     REF. 7; PAGE 315
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n
>USING A PRE-ALLOCATED DATASET FOR UNIT FT17F001.
>USING A PRE-ALLOCATED DATASET FOR UNIT FT18F001.


          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.   PLOTTER / PAGE SIZE
     2.   GRAPH LIMITS
     3.   HEADING
     4.   NO ADDITIONAL CHANGES - PLOT POLE-ZERO
          MAP
     5.   NO CHANGES - EXIT POLE-ZERO PLOTTING
          ROUTINE
ENTER OPTION NUMBER.
5


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3

               OPTGRAPH

OPEN LOOP TRANSFER FUNCTION

     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER OPTION NUMBER.
7

               OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
4
```

```
R; T=2.80/4.67 19:45:15
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.1 .

b. Example of Tabular Data (Terminal Session)

The entering and exiting option menus for the tabular data terminal session are identical to the graphic response terminal session option menus, and have been eliminated from the following terminal session.

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 19:51:03
EXECUTION BEGINS...


           POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
2


           POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TABULAR OUTPUT TO GO TO:
     1.  SCREEN
     2.  PRINTER
     3.  DISK (OPGRAPH LISTING)
ENTER OPTION NUMBER.
1
```

```
           POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
     INPUT NUMBER =        1
     OUTPUT NUMBER =       1
     TRANSFER FUNCTION (DC) GAIN =  0.1000D+01

     DENOMINATOR ORDER =    4
POLE LOCATIONS
       REAL PART         IMAGINARY PART
       0.0000D+00        0.0000D+00
       0.1000D+01        0.0000D+00
      -0.2000D+01        0.3464D+01
      -0.2000D+01       -0.3464D+01

     NUMERATOR ORDER =    1
ZERO LOCATIONS
       REAL PART         IMAGINARY PART
      -0.1000D+01        0.0000D+00

DO YOU DESIRE TO CHANGE OUTPUT DEVICE?
     TYPE "YES" OR "NO".
n


           POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION

DO YOU DESIRE:

     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE

ENTER OPTION NUMBER.
3

R; T=1.60/3.23 19:53:00
record off
```

END RECORDING OF TERMINAL SESSION

3. Root-Locus

The subroutine RTLO creates a closed loop system (with negative unity feed-back) from the selected transfer function input numbers and output numbers. Transfer function poles and zeros are formed into two separate polynomials by the subroutine MAKPOL. The numerator polynomial (zeros) is multiplied by the gains, and the two polynomials are added to form a single polynomial. Complex roots of the of the polynomial are calculated by the IMSL library subroutine ZRPOLY. The complex roots are separated into real and imaginary components for either plotting or tabulating.

The plotting routine first plots the transfer function pole and zero locations then plots the root locations as they are received from the subroutine ZRPOLY. For the plotting routine the gain interval specified by the user is divided into 2000 evenly spaced points for the subroutine ZRPOLY to calculate roots. The poles, zeros, and roots are plotted within the plot limits specified by the user.

For the tabular data routine the user is given the option to choose between 1 and 500 points for the subroutine ZRPOLY to calculate roots. The tabular data output provided for the user is system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, the pole and zero locations, and the root locus gains and roots

A positive unity feedback system may be analyzed by specifying a negative gain range vice a positive gain range.

4. Root-Locus (Interactive Example)

The following interactive example is of the open loop transfer function for an aircraft with an autopilot in the longitudinal mode described in Pole-Zero interactive section.

a. Example of Graphic Response (Terminal Session)

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 20:28:37
EXECUTION BEGINS...


               OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
1


               OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS
CONTAINS:
     1.  NUMBER OF STATES =                 4
     2.  NUMBER OF CONTROLS (INPUTS) =      1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) = 1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


               OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
AND/CR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?
1
     OUTPUT # ?
1


              OPTGRAPH

OPEN LOCP TRANSFER FUNCTION
     INPUT #  =  1
     CUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROCT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUI/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER CPTION NUMBER.
2


          ROOT-LOCUS
OPEN LOCP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER CPTION NUMBER.
1
```

```
          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
PLOTTER SELECTION AND PAGE SIZE
(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
 SELECTION OF TEK618)

     WHICH PLOTTER DO YOU DESIRE:
          1. TEK618
          2. VERSATEC
     CHOOSE OPTION 1 OR 2
2
      PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                 INCHES)
          HEIGHT =
6
          WIDTH =
8


PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM = ?
-15
          X MAXIMUM = ?
5
     Y AXIS (IMAGINARY AXIS)
          Y MINIMUM = ?
-5
          Y MAXIMUM = ?
5

PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM =   -15.00
          X MAXIMUM =     5.00
     Y AXIS (IMAGINARY AXIS)
```

```
          Y MINIMUM =    -5.00
          Y MAXIMUM =     5.00
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n


GAIN RANGE FOR ROOT-LOCUS PLOT
          MINIMUM GAIN = ?
0
          MAXIMUM GAIN = ?
500

GAIN RANGE FOR ROOT-LOCUS PLOT
          MINIMUM GAIN =       0.000D+00
          MAXIMUM GAIN =       0.500D+03
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n


PLOT HEADING
     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3 MAX )
          ENTER NUMBER OF LINES.
          (ENTER "0" FOR NO HEADING)
3
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLOWED
     LINE 1 IS:
aircraft with an autopilot in
     LINE 2 IS:
the longitudinal mode
     LINE 3 IS:
ref. 7; page 315

PLOT HEADING
```

```
     LINE 1 :     AIRCRAFT WITH AN AUTOPILOT IN
     LINE 2 :     THE LONGITUDINAL MODE
     LINE 3 :     REF. 7; PAGE 315
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n
>USING A PRE-ALLOCATED DATASET FOR UNIT FT17F001.
>USING A PRE-ALLOCATED DATASET FOR UNIT FT18F001.


          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.  PLOTTER / PAGE SIZE
     2.  GRAPH LIMITS
     3.  HEADING
     4.  GAIN RANGE
     5.  NO ADDITIONAL CHANGES - PLOT ROOT-LOCUS
     6.  NO CHANGES - EXIT ROOT-LOCUS PLOTTING
         ROUTINE
ENTER OPTION NUMBER.
6


          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3
```

```
                    OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER OPTION NUMBER.
7


                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
4
R; T=12.36/15.14 20:32:54
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.2 .

b. Example of tabular data (Terminal Session)

The entering and exiting option menus for the tabular data terminal session are identical to the graphic response terminal session option menus, and have been eliminated from the following terminal session.

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 20:42:59
EXECUTION BEGINS...


             ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
2
              ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TABULAR OUTPUT TO GO TO:
     1.  SCREEN
     2.  PRINTER
     3.  DISK (OPGRAPH LISTING)
ENTER OPTION NUMBER.
1

GAIN RANGE FOR ROOT-LOCUS PLOT
          MINIMUM GAIN = ?
1
          MAXIMUM GAIN = ?
5
```

```
GAIN RANGE FOR ROOT-ICCUS PLOT
          MINIMUM GAIN =       0.100D+01
          MAXIMUM GAIN =       0.500D+01
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NC".
n

HOW MANY PCINTS DO YCU WANT TO TABULATE?
     (500 IS THE MAXIMUM)
ENTER NUMBER OF POINTS.
5

          ROOT-LOCUS
OPEN LOCP TRANSFER FUNCTION
     INPUT NUMBER =       1
     CUTPUT NUMBER =      1
     TRANSFER FUNCTICN (DC) GAIN =  0.1000D+01
OPEN ICCP TF POLES ANI ZEROS

     DENCMINATOR ORDER =    4
     POLE LOCATIONS
       REAL PART         IMAGINARY PART
       0.0000D+00        0.0000D+00
       0.1000D+01        0.0000D+00
      -0.2000D+01        0.3464D+01
      -0.2000D+01       -0.3464D+01

     NUMERATOR ORDER =    1
     ZERC LOCATIONS
       REAL PART         IMAGINARY PART
      -0.1000D+01        0.0000D+00

     GAIN =   0.1000C+01
       REAL PART         IMAGINARY PART
       0.7074D-01        0.0000D+00
       0.8962D+00        0.0000D+00
      -0.1983D+01        0.3441D+01
```

```
         -0.1983D+01       -0.3441D+01

        GAIN =    0.1800D+01
           REAL PART         IMAGINARY PART
           0.1453D+00        0.0000D+00
           0.7948D+00        0.0000D+00
          -0.1970D+01        0.3422D+01
          -0.1970D+01       -0.3422D+01

        GAIN =    0.2600D+01
           REAL PART         IMAGINARY PART
           0.2576D+00        0.0000D+00
           0.6552D+00        0.0000D+00
          -0.1956D+01        0.3402D+01
          -0.1956D+01       -0.3402D+01

        GAIN =    0.3400D+01
           REAL PART         IMAGINARY PART
           0.4426D+00        0.1661D+00
           0.4426D+00       -0.1661D+00
          -0.1943D+01        0.3383D+01
          -0.1943D+01       -0.3383D+01

        GAIN =    0.4200D+01
           REAL PART         IMAGINARY PART
           0.4285D+00        0.3096D+00
           0.4285D+00       -0.3096D+00
          -0.1929D+01        0.3363D+01
          -0.1929D+01       -0.3363D+01
   DO YCU DESIRE TO MAKE ANY CHANGES ?
        TYPE "YES" OR "NC".
   y

             ROOT-LOCUS
   OPEN ICCP TRANSFER FUNCTION
   DO YOU DESIRE TO MAKE ANY CHANGES TO:
        1.  OUTPUT DEVICE
```

```
     2.  GAIN RANGE
     3.  NUMBER OF POINTS CALCULATED
     4.  NO ADDITIONAL CHANGES - TABULATE DATA
     5.  EXIT ROOT-LOCUS TABULAR DATA ROUTINE
ENTER OPTION NUMBER.
5

          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3

R; T=1.63/3.40 20:44:54
record off
END RECORDING OF TERMINAL SESSION
```

G. FREQUENCY RESPONSE ANALYSIS

The calculations for the frequency response of the Bode, Nyquist, and Nichols responses are identical. The only difference is in the graphical presentation of the calculated data. The subroutines BODE, NYQST, and NICHOLS call the subroutine FREQ to calculate the transfer function magnitude and phase for the frequency range specified by the user.

The subroutine FREQ eliminates the extraneous zeros by comparing the zeros to the Markov parameter as described in the Characteristic Equation Analysis section. The frequency response magnitude and phase are calculated using double precision complex library functions following the conventions of the IBM System /360/370/ FORTRAN IV language. The frequency response is calculated by determining the product of successive numerator zeros which have been combined with the frequency and divided by the product of successive denominator poles which also have been combined with the frequency. The magnitude for the complex result of the zeros, poles, and frequency calculations is determined using the FORTRAN double precision library functions for finding the magnitude of a complex argument. The phase of the of the complex result is determined by separating the real and imaginary parts of the complex results, and finding the phase angle using the double precision FORTRAN library function arctangent. The angle is converted from radians to degrees and is corrected for proper quadrant by checking the signs of the real and imaginary parts. The normal range for calculating phase angles by the subroutine is from +540 degrees to -540 degrees. This range is considered adequate for most application, but should these limits be exceeded the plot will jump with a vertical line to either +360 degrees or -360 degrees respectively before continuing with the plot.

For a graphic response the user specified frequency range is divided into 500 equally spaced points (on a logrithmic scale) for which to calculate the magnitude and phase. The user is given the option to select between 1 and 500 points for tabular data.

1. Bode Response

The graphic response section of the subroutine BODE creates two plots. The first plot is the response magnitude in decibels versus the frequency in radians per second. The magnitude from the subroutine FREQ is converted to decibels and plotted with its corresponding frequency. The second plot is of the phase in degrees versus frequency in radians per second. The phase from the subroutine FREQ is plotted with its corresponding frequency. The frequency for both plots is plotted on a logrithmic scale. The scale range for both is set automatically to include the entire range of data to be plotted by the subroutine MINMAX which scans the data for the maximum and minimum values. System information (tranfer function input number, output number, and (DC) gain) is listed in the graph legend.

The magnitude in decibels and the phase in degrees is searched for "0" decibel and 180 degree crossover points to calculate the phase and gain margins.

The tabular response section gives the user the option to select the the number of frequency points to be calculated between 1 and 500 for the frequency range he has specified. For tabular data response the user is given system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, and the frequency (radians per second), magnitude (decibels), phase (degrees), and the real and imaginary frequency response parts.

2. Bode Response (Interactive Example)

The following example of compensator transfer function with a filter and regulator was obtained from [Ref. 8,pp. 382 - 384].

The compensated system is represented by:

$$[C] = [\ -254.1 \quad -19.57\ ]$$

$$[D] = [0]$$

$$[F] = \begin{vmatrix} 0. & 1.0 \\ 0. & -4.6 \end{vmatrix}$$

```
[G] = |  0.   |
      | 0.787 |


[GAM] = | 0.  |
        | 0.1 |


[H] = [ 1.  0. ]


[K] = |  95.4 |
      | 4561. |


[Q] = [10.]
```

a. Example cf Graphic Response (Terminal Session)

```
BEGIN RECCRDING OF TERMINAL SESSION
R; T=0.01/0.02 18:30:23
graphics
EXECUTION BEGINS...


                     OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
3


                     OPTGRAPH
```

```
THE COMPENSATOR TRANSFER SYSTEM OBTAINED FRCM
OPTSYS CCNTAINS:
     1.   NUMBER OF STATES =                   2
     2.   NUMBER OF CONTROLS (INPUTS)  =       1
     3.   NUMBER OF MEASUREMENTS (OUTPUTS) =   1
     4.   MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


               OPTGRAPH

AN OPEN ICOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
AND/OR NICHOLS PLOT IS DESIRED FOR:
         INPJT # ?
1
         CUTPUT # ?
1


               OPTGRAPH

COMPENSAICR TRANSFER FUNCTION
     INPUI #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.   EOLE-ZERO MAP
     2.   ROOT-LOCUS
     3.   EODE
     4.   NYQUIST (POLAR PLOT)
     5.   NICHOLS
     6.   ANOTHER INPUT/OUTPUT COMBINATION (SAME
          TRANSPER FUNCTION)
     7.   ANOTHER TYPE TRANSFER FUNCTION /EXIT
          CPTGRAPH
ENTER OPIICN NUMBER.
```

```
3

          BODE PLOT
COMPENSATCR TRANSFER FJNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTICN NUMBER.
1

          BODE PLOT
COMPENSATCR TRANSFER FUNCTION
PLOTTER SELECTION AND PAGE SIZE
(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
 SELECTICN OF TEK618)
     WHICH PLOTTER DO YOU DESIRE:
          1. TEK618
          2. VERSATEC
     CHOCSE OPTION 1 OR 2
2
     PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                INCHES)
          HEIGHT =
5.65
          WIDTH =
8.5

PLOTTING LIMITS FOR GRAPH
     FREQUENCY RANGE - RADIANS PER SECOND
          MINIMUM FREQUENCY = ?
0.1
          MAXIMUM FREQUENCY = ?
1000000

PLOTTING LIMITS FOR GRAPH
     FREQUENCY RANGE - RADIANS PER SECOND
```

```
          MINIMUM FREQUENCY =       0.100E+00
          MAXIMUM FREQUENCY =       0.100E+07
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n

PLOT HEADING
     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3 MAX )
          ENTER NUMBER OF LINES.
            ( ENTER "0" FOR NO HEADING )
2
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLOWED
     LINE 1 IS:
filter simulation
     LINE 2 IS:
ref. 8; pages 332 - 334

PLOT HEADING
     LINE 1 :     FILTER SIMULATION
     LINE 2 :     REF. 8; PAGES 332 - 334
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n


          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          GAIN MARGIN AND PHASE MARGIN
PHASE CROSSOVER FREQUENCY IS   75.1184 RAD/SEC;
         GAIN MARGIN IS   -59.8906 DB
GAIN CROSSOVER FREQUENCY IS ********** RAD/SEC;
         PHASE MARGIN IS  -89.9480 DEG
          CLEAR SCREEN TO CONTINUE
```

```
              BODE PLOT
COMPENSATCR TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.   PLOTTER / PAGE SIZE
     2.   GRAPH LIMITS (FREQUENCY RANGE)
     3.   HEADING
     4.   NO ADDITIONAL CHANGES - PLOT BODE PLCTS
     5.   NO CHANGES - EXIT BODE SUBROUTINE
ENTER OPTICN NUMBER.
5

              BODE PLOT
COMPENSATCR TRANSFER FUNCTION
DO YOU DESIRE:
     1.   GRAPHICAL OUTPUT
     2.   TABULAR DATA
     3.   QUIT SUBROUTINE
ENTER OPTICN NUMBER.
3


                   OPTGRAPH

COMPENSATCR TRANSFER FUNCTION
     INPUT #  =   1
     OUTPUT # =   1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.   POLE-ZERO MAP
     2.   ROOT-LOCUS
     3.   BODE
     4.   NYQUIST (POLAR PLOT)
     5.   NICHOLS
     6.   ANOTHER INPUT/OUTPUT COMBINATION (SAME
          TRANSFER FUNCTION)
     7.   ANOTHER TYPE TRANSFER FUNCTION /EXIT
          CPTGRAPH
ENTER OPTION NUMBER.
7


                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.   OPEN LOOP TRANSFER FUNCTION
     2.   NOISE TRANSFER FUNCTION
     3.   COMPENSATOR TRANSFER FUNCTION
     4.   EXIT OPTGRAPH
ENTER OPTION NUMBER.
4
R; T=7.01/8.84 18:39:11
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.3 and figure 3.4 .

b. Example of Tabular Data Listing File

The terminal session for the Bode tabular data response is similar to the Bode graphic response terminal session. Appendix D contains an example of tabular output sent to a disk (OPGRAPH LISTING) for five points between 10 and 100 radians/second.

3. Nyquist Respcnse

The graphic response section of the subroutine NYQST creates a polar plot from the magnitude and phase data received from the subroutine FREQ. The plot is automatically scaled from a minimum radius of one by using the subroutine MINMAX to determine the maximum phase and magnitude values. The gain / phase margin calculations and the tabular data output are identical to the subroutine BODE.

4. Nyquist Response (Interactive Example)

The following example is of the open loop transfer function for the filter simulation example described in the Bode interactive section.

This example follows at the end of the chapter as figure 3.5 .

5. Nichols Response

The graphic response section of the subroutine NICHCI creates a single rectangular plot of magnitude in decibels versus phase in degrees. The magnitude from the subroutine FREQ is converted to decibels and plotted with the corresponding magnitude. The plot is automatically scaled using the subroutine MINMAX to determine the maximum phase and magnitude values. The gain / phase margin calculations and the tabular data output are identical to the subroutine BODE.

6. Nichols Response (Interactive Example)

The following example is of the open loop transfer function for the filter simulation example described in the Bode interactive section.

This example follows at the end of the chapter as figure 3.6 .

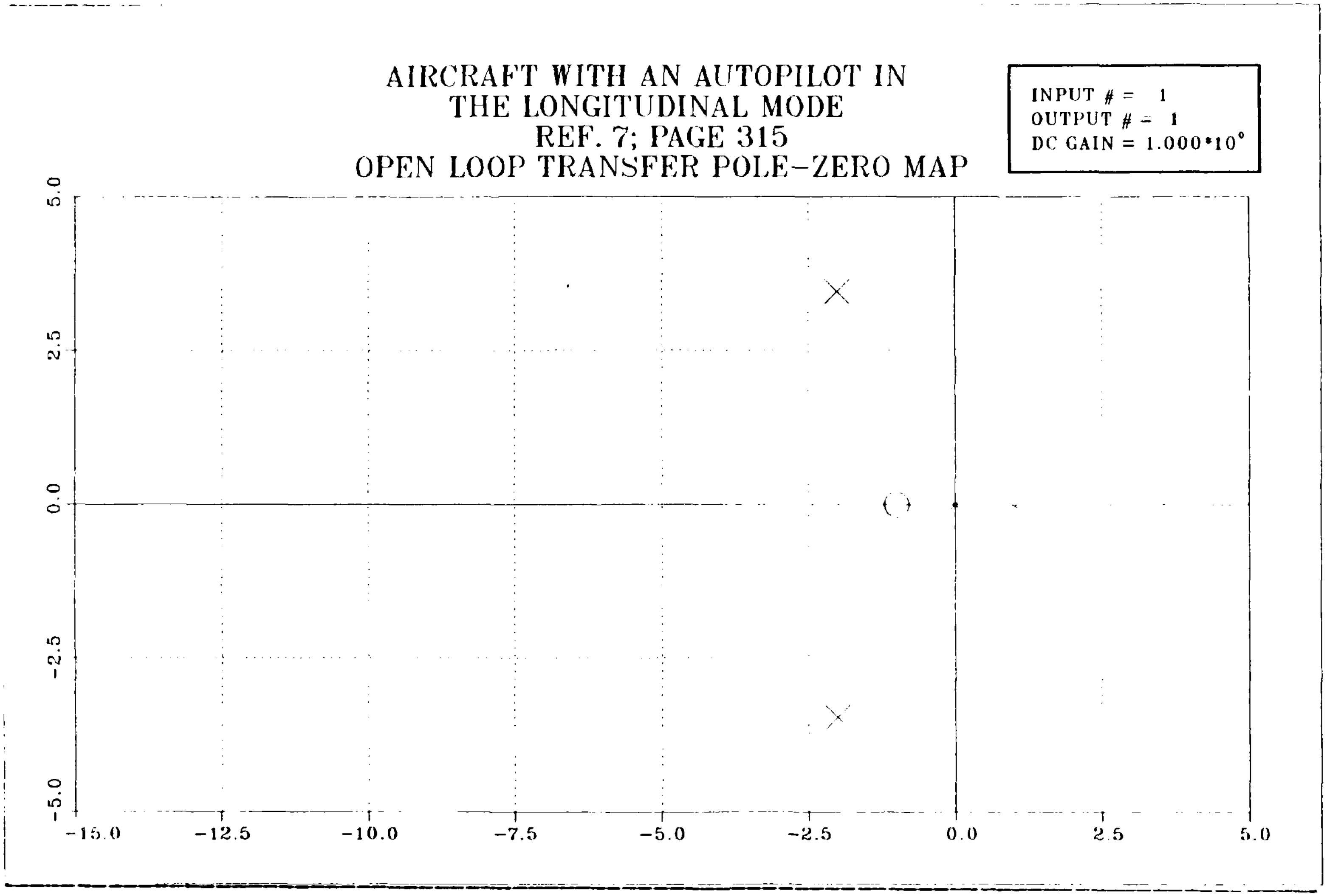

Figure 3.1 Pole-Zero Map Example.

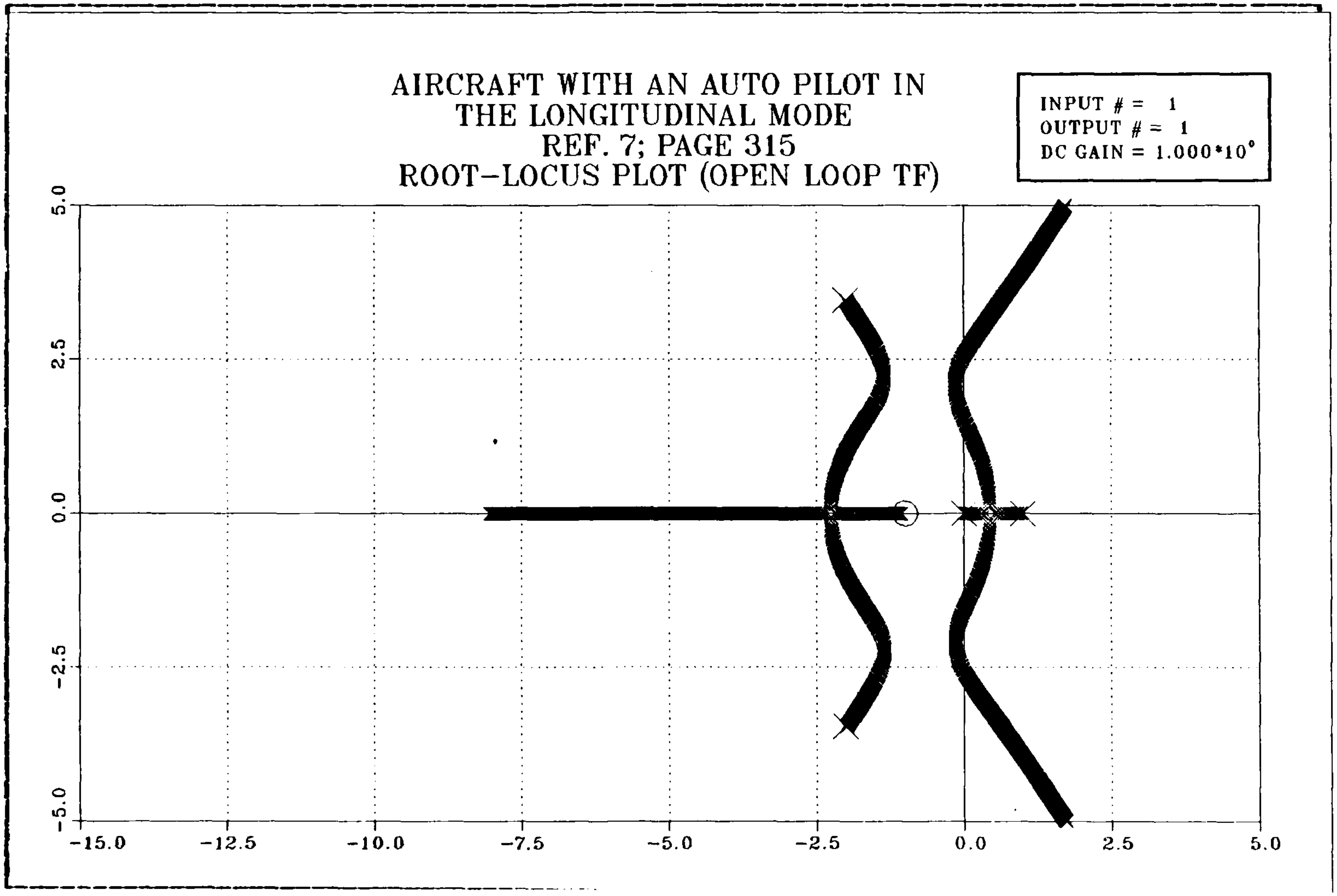

Figure 3.2 Root Locus Response Example.

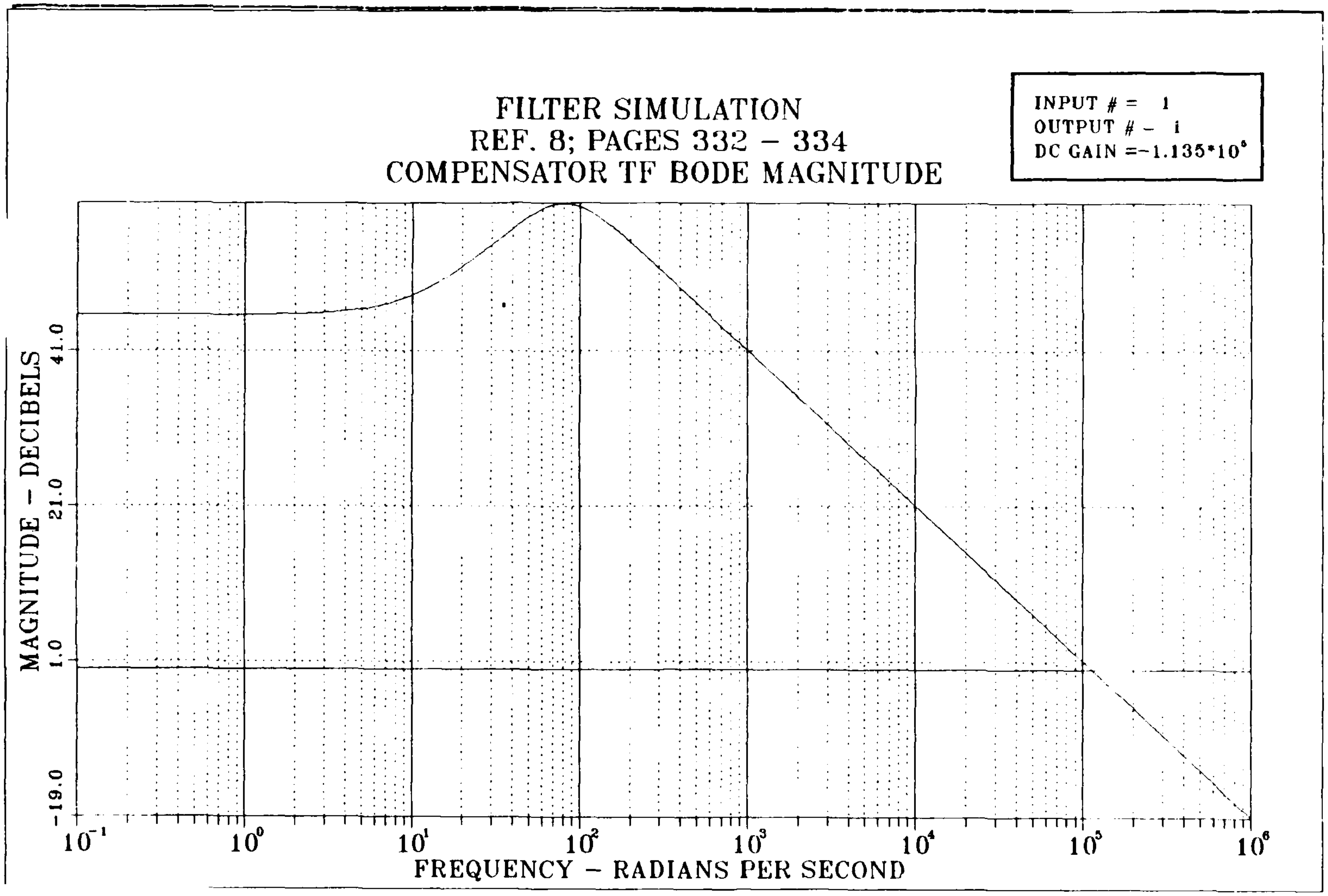

Figure 3.3 Bode Response Example (Magnitude).

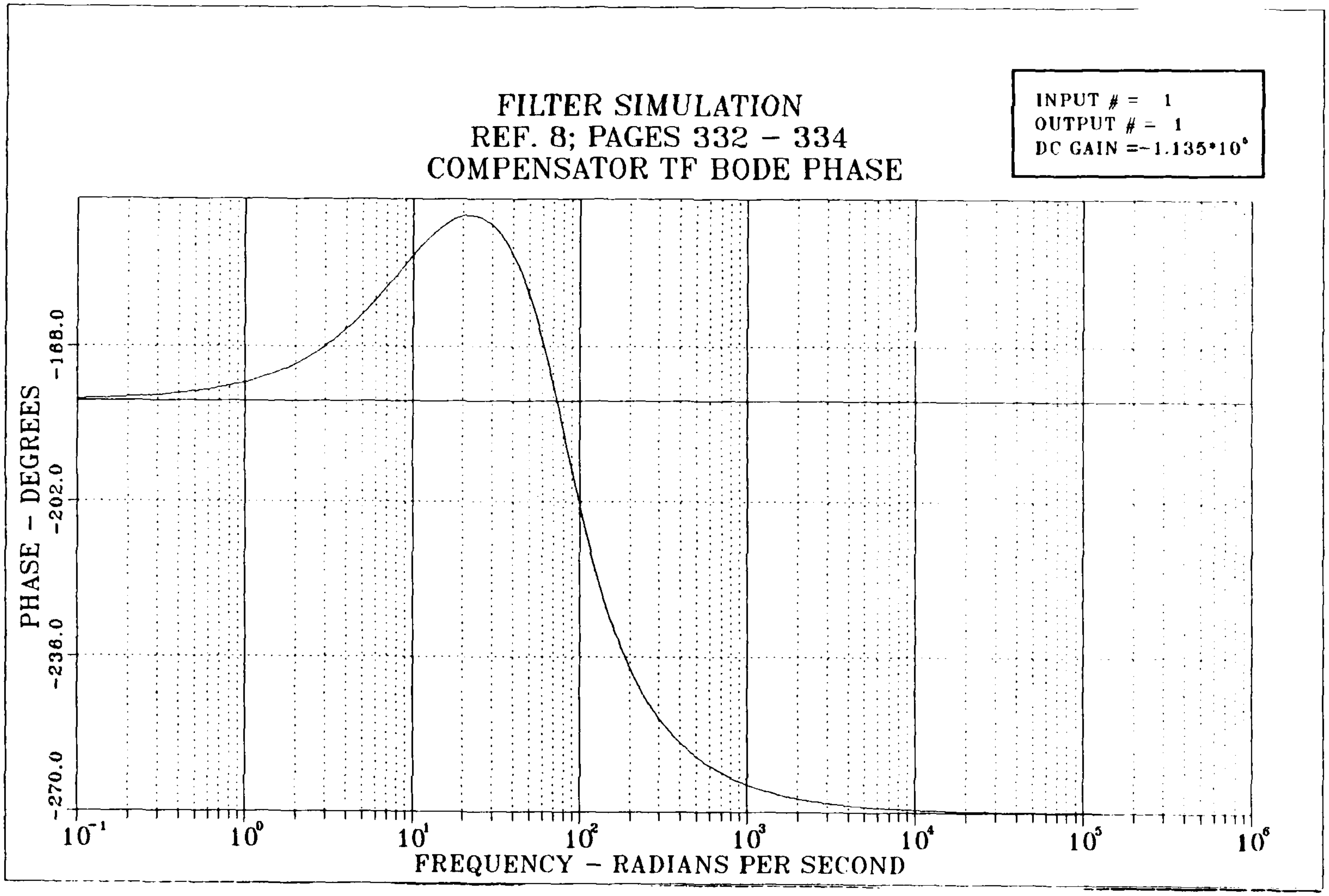

Figure 3.4 Bode Response Example (Phase).

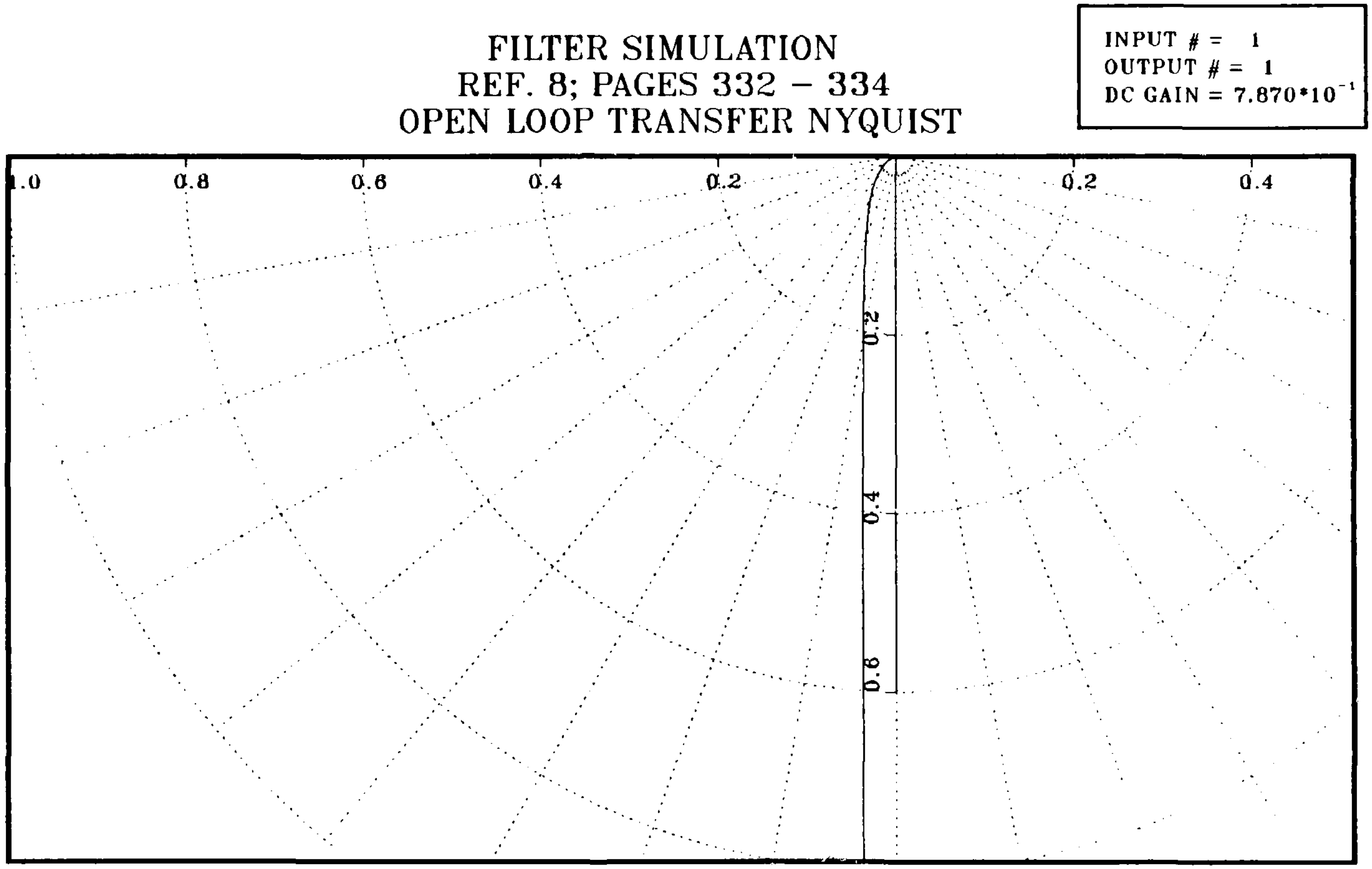

Figure 3.5   Nyquist Response Examгle.

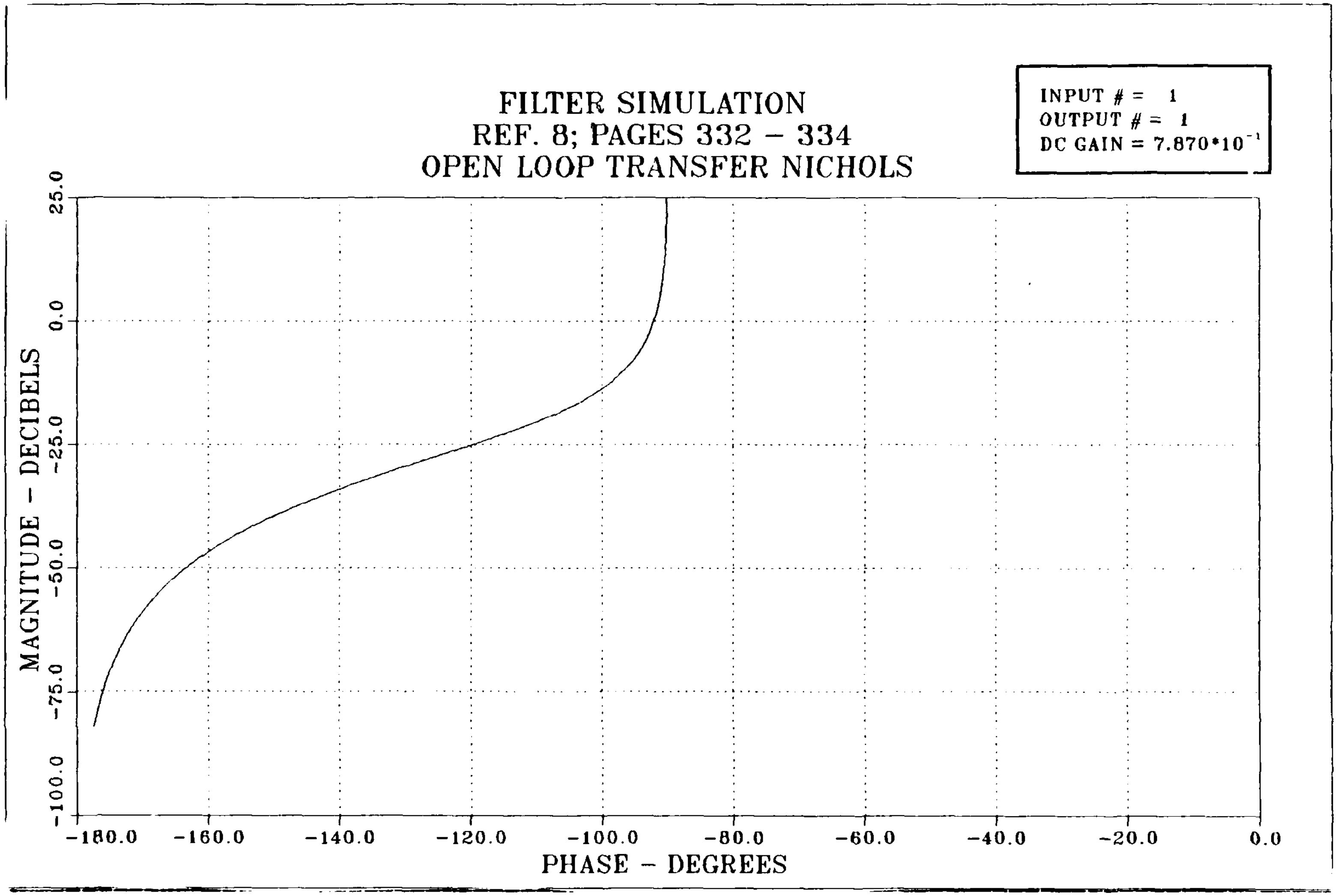

Figure 3.6 Nichols Response Example.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CCNCIUSIONS

An evaluation of the computational ability of OPTSYSX and CPTGRAPH, the program was tested using an 82 X 82 matrix, provided by NASA-Edwards, of longitudinal equations for the X-29A experimental forward-swept wing fighter aircraft prototype. The OPTSYSX program array had to be redimensioned and a 2-megabyte virtual machine size was required for a system of this size.

The open loop eigenvalues calculated by the OPTSYSX program compared favorably with the Eigensystem data supplied by NASA-Edwards, but the OPTSYSX program failed in calculating the open loop transfer function zeros. Extraneous zeros (calculated by OPTSYSX) were of the same approximate magnitude as the open loop system zeros. This prevented the identification and elimination of the extraneous zeros by comparison with the Markov parameter. The open loop zero identification was further complicated by not having available open loop transfer function zero information from NASA-Edwards to compare the OPTSYSX results to.

When requested for additional information NASA-Edwards provided a computer tape with a revised 98 X 98 matrix of longitudinal motion equations for the X-29A fighter aircraft. For this revised system, the OPTSYSX program requires a virtual machine size in excess of 2-megabyte. Time constraints have prevented running the OPTSYSX program with the revised system.

The OPTGRAPH program was tested using the OPTSYSX program's open loop Eigenvalue and transfer function cutput data for the X-29A 82 X 82 system of longitudinal motion equations. OPTGRAPH provided excellent quality Bode plots for all of the open loop transfer function inputs and outputs and did not exhibit any computational difficulties as indicated by the lack of error messages at the end of the test. While the test results are encouraging as to the ability of the OPTGRAPH program to assist in the analysis of large order systems, the actual computational accuracy of the OPTGRAPH program can not be fully verified until accurate transfer function information can be obtained from the OPTSYSX program.

B. RECOMMENDATIONS

Based on the results of this Thesis the following areas emerged as possible areas for further research and study.

1. Root Finding Routines

The OPTSYSX program has two similar root finding subroutines (HQR and HQR2), to find the transfer function Eigensystem (poles) and zeros. The order of the transfer function numerator is calculated separately in the subroutine ZEROS.

The inclusion of the open loop transfer function eigensystem (pole locations), zero locations, transfer function numerator orders, and transfer function gains, for the revised (98 X 98) longitudinal mode system by NASA-Edwards should simplify the locating the problem in calculating the transfer function zeros.

The open loop system data from NASA-Edwards also included Bode magnitude and phase plots, and gain and phase margin information, which can be used to evaluate more conclusively the OPTGRAPH program's ability to help evaluate a large order system.

2. Program Memory Requirements

The OPTSYSX program requires in excess of 2-megabyte of virtual machine memory when configured for large matrix operations (98 X 98). Virtual machines with this memory capacity are not normally available to a user. The memory usage for matrix storage and manipulation is a possible area for the reduction in program memory requirement size. The OPTSYSX program retains most of its computational arrays in memory. This method simplifies programming but is extremely inefficient in its use of virtual machine memory.

3. Further Modifications

The area of modern digital controls should be further investigated. The computational abilities of the OPTGRAPH program make it readily adaptable, with minor modifications, for assisting in the analysis of transfer functions in the digital domains.

APPENDIX A

OPTSYS EXEC LISTING

```
    &TRACE OFF
************************************************************
*                     THE OPTSYS EXEC
*           CONTROLS THE OPTSYSX, OPTCALC AND OPTPLOT
*           TO DETERMINE THE TIME RESPONSE OF A SYSTEM.
*                        BY H. A. DIEL
*                   VERSION 1.0   16 JULY 1984
*                    MODIFIED BY M. H. LAPTAS
************************************************************
CLRSCRN
&BEGTYPE -ENDFOUR




************************************************************

      OUTPUT FROM OPTSYSX WILL COME TO THE SCREEN IF YOU
               WISH DISK FILE
               ENTER  D    ANY OTHER INPUT YIELD SCREEN

************************************************************

-ENDFOUR
&READ VARS &ANS
&IF .&ANS NE .D &GOTO -ONE
FILEDEF 06 DISK OUTPUTX LISTING A1
CLRSCRN
&BEGTYPE -ENDSIX
```

```
************************************************************

        OUTPUT WILL GO TO DISK FILE 'OUTPUTX LISTING A1'

************************************************************
-ENDSIX
CP SLEEP 3 SEC
-ONE
CLRSCRN
CP LINK 0039P 191 251 RR
ACC 251 F
************************************************************
*                                                          *
*      ALLOW THE USE OF AN OLD "OPTMAT DATA A1"            *
*                                                          *
************************************************************
RENAME OPTMAT DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -FIRST
RENAME OPTSYS DATA A1 OPTMAT DATA A1
FINDSTAK OPTMAT DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2
&IF .&A2 NE .1 &GOTO -START
CLRSCRN
&BEGTYPE -ENDTWO


************************************************************

     YOU HAVE A DATA FILE NAMED 'OPTMAT DATA' ON YOUR A
     DISK  THAT WAS PREVIOUSLY GENERATED BY THE  OPTSYS
     PROGRAM  AND  CONTAINS THE F, G, H, GAMMA, A AND B
     MATRICES FROM THAT RUN.
     IF  YOU WOULD LIKE TO USE THESE SAME MATRICES  FOR
     THIS  RUN, THE  CPTSYS  PROGRAM  WILL  READ IN THE
     DESIRED DATA AT THE APPROPRIATE TIME,

                   IF YOU TYPE (Y) ES.

     ANY OTHER INPUT WILL RESULT IN THAT FILE BEING ERASED!

*************************************************************
-ENDTWO
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTO -START
-FIRST
*************************************************************
*                                                           *
*      ERASE THE OLD "CPTMAT DATA A1" DATA FILE             *
*     PLACE "000 0" IN THE NEW "OPTMAT DATA FILE"           *
*     TO ACT AS A FLAG FOR OPTSYSX  AND OPTCALC             *
*                                                           *
*************************************************************
ERASE OPTMAT DATA A1
&STACK 000 0
FILESTCK OPTMAT DATA A1 F 80 1
-START
CLRSCRN
&BEGTYPE -ENDONE


      THE OPTSYS EXEC CONTROLS FOUR PROGRAMS:

         1  OPTSYSX FCRTRAN  (SYSTEM ANALYSIS)
              GENERATES OPTMAT AND OPTGRAPH DATA SETS
              - RERUN USES OPTMAT
         2  OPTCALC FCRTRAN  (CALCULATE TIME RESPONSE)
              GENERATES OPTPLOT DATA SET  USES OPTMAT FROM
              OPTSYSX
         3  OPTGRAPH FORTRAN  (POLE-ZERO, ROOT-LOCUS, BCDE,
            NYQUIST, ETC)
              USES OPTGROL -OPTGRNO -OPTGRCM FROM OPTSYSX
         4  EXIT

           OPTPLOT FORTRAN IS THE FOURTH PROGRAM
              USES OPTPLOT DATA SET FROM OPTCALC
      THE SIZE OF THE DATA SETS VARY WITH THE SYSTEM
      ORDER, AND CAN USE ABOUT 20% OF THE USERS DISK SPACE.
      THEREFORE ENSURE THAT SUFFICIENT DISK SPACE IS
      AVAILABLE.
          IF DATA SET IS ALREADY AVAILABLE YOU MAY RUN ANY
          PROGRAM
        - ENTER  1 , 2 ,  3 ,  4     ANY OTHER INPUT
                                    RETURNS TO MENU
-ENDONE
&READ VARS &ANS
&IF .&ANS EQ .1 &GOTO -OPTSYS
&IF .&ANS EQ .2 &GOTO -OPTCALC1
&IF .&ANS EQ .3 &GOTO -OPGRAPH1
&IF .&ANS EQ .4 &EXIT &RC
&GOTO -START
-OPTSYS
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 9 DISK OPTMAT DATA A1 (PERM
FILEDEF 10 DISK OPTGROL DATA A1 (PERM
FILEDEF 01 DISK OPTGRNO DATA A1 (PERM
FILEDEF 04 DISK OPTGRCM DATA A1 (PERM
GLOBAL TXTLIB VFORTLIB IMSLDP  NONIMSL
&TYPE LOADING OPTSYS.... GENERAL STATE VARIABLE ANALYSIS
   PROGRAM
&TYPE....   OPTMAT DATA A1 ..... INPUT DATA SET ON RERUNS
OPTSYSX
CLRSCRN
&TYPE... DATA SETS  .. OPTMAT   AND  .. OPGRAPH  CREATED
CP SLEEP 5 SEC
```

```
&GOTO -START
-OPTCALC1
***********************************************************
*                                                         *
*           CHECK FOR DATA IN THE FILE "OPTMAT DATA "     *
*                    BEFORE LOADING OPTCALC               *
*                                                         *
***********************************************************
FINDSTAK OPTMAT DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2
&IF .&A2 EQ .1 &GOTO -OPTCALC
&TYPE PROPER DATA FILE IS NOT AVAILABLE FOR OPTCALC
CP SLEEP 5 SEC
&GOTO -START
-OPTCALC
&TYPE.........OPTCALC.... TIME RESPONSE PROGRAM
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 9 DISK OPTMAT DATA A1 (PERM
GLOBAL TXTLIB VFORTLIB IMSLDP  NONIMSL
OPTCALC
&TYPE    .. OPTPLOT DATA A1   CREATED
CP SLEEP 5 SEC
CLRSCRN
&BEGTYPE -ENDNINE



***********************************************************


         IF YOU ARE DISSATISFIED WITH THE RESULTS
         THUS FAR AND WOULD LIKE TO EXIT TO CMS,

                 -TYPE 'Y' TO EXIT-

            (ANY OTHER INPUT TO CONTINUE)
```

```
***********************************************************
-ENDNINE
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTO -START
&TYPE PLOTS NEXT
CP SLEEP 4 SEC
GLOBAL TXTLIB DISLIBVS 92DISLIB 92INTLIB VFORTLIB GRFLIB
   NONIMSL CMSLIB
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 11 DISK LBLANK TMP A3 (RECFM F LRECL 2400 BLKSIZE
   2400 BLKSIZE 2400 XTENT 600
FILEDEF 12 DISK ISSCCMAP MAPDTA * (RECFM F LRECL 400
   BLKSIZE 400
FILEDEF 13 DISK TABLET TMP A3 (RECFM VS LRECL 208 BLKSIZE
   208 XTENT 1000
FILEDEF 14 DISK LBLANK MAPDTA &LBMODE (RECFM VS LRECL 608
   BLKSIZE 608
FILEDEF 17 DISK DISSPLA SYSUT1 A3 (RECFM FB LRECL 2000
   BLOCK 2000 XTENT 500
FILEDEF 18 DISK DISSPLA METAFILE A4 (RECFM VBS LRECL 19065
   BLOCK 19069
OPTPLOT
&GOTO -META
-OPGRAPH1
***********************************************************
*                                                         *
*           CHECK FOR DATA IN THE OPTGRAPH DATA SETS "    *
*                    BEFORE LOADING OPGRAPH               *
*                                                         *
***********************************************************
***********************************************************
RENAME OPTGROL DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -OPTNOISE
RENAME OPTSYS DATA A1 OPTGROL DATA A1
```

```
FINDSTAK OPTGRCL DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-OPTNOISE
RENAME OPTGRNO DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -OPTCOMP
RENAME OPTSYS DATA A1 OPTGRNO DATA A1
FINDSTAK OPTGRNO DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-OPTCOMP
RENAME OPTGRCM DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -NODATA
RENAME OPTSYS DATA A1 OPTGRCM DATA A1
FINDSTAK OPTGRCM DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-NODATA
&PRINT PROPER DATA FILE IS NOT AVAILABLE FOR OPGRAPH
CP SLEEP 5 SEC
&GOTO -START
-SIXTEEN
&TYPE  ...OPTGRAPH.... CLASSICAL ANALYSIS OF OPTSYS OUTPUT
SET LDRTBLS 10
GLOBAL TXTLIB DISLIBVS 92DISLIB 92INTLIB VFORTLIB GRFLIB
   NONIMSL CMSLIB
SET LDRTBLS 10
FILEDEF 01 DISK OPTGRNO DATA A1 (PERM
FILEDEF 02 DISK OPGRAPH LISTING A1
FILEDEF 03 PRINTER (RECFM FA BLKSIZE 133 PERM
FILEDEF 04 DISK OPTGRCM DATA A1 (PERM
FILEDEF 06 TERM (RECFM FA BLKSIZE 133
FILEDEF 05 TERM (RECFM FA BLKSIZE 80
FILEDEF 10 DISK OPTGRCL DATA A1 (PERM
FILEDEF 11 DISK LBLANK TMP A3 (RECFM F LRECL 2400 BLKSIZE
   2400 XTENT 600
FILEDEF 12 DISK ISSCCMAP MAPDTA * (RECFM F LRECL 400
   BLKSIZE 400
FILEDEF 13 DISK TABLET TMP A3 (RECFM VS LRECL 208 BLKSIZE
   208 XTENT 1000
FILEDEF 14 DISK LBLANK MAPDTA &LBMODE (RECFM VS LRECL 608
   BLKSIZE 608
FILEDEF 17 DISK DISSPLA SYSUT1 A3 (RECFM FB LRECL 2000
   BLOCK 2000 XTENT 500
FILEDEF 18 DISK DISSPLA METAFILE A4 (RECFM VBS LRECL 19065
   BLOCK 19069
OPTGRAPH
-META
***********************************************************
*                                                         *
*           CHECK FOR FILE "DISSPLA METAFILE A4" ON       *
*           THE USER'S DISK BEFORE GOING TO DISSPOP       *
*                                                         *
***********************************************************
RENAME DISSPLA METAFILE A4 OPTSYS METAFILE A4
&IF &RETCODE NE 0 &GOTO -START
RENAME OPTSYS METAFILE A4 DISSPLA METAFILE A4
-EIGHT
CLRSCRN
&BEGTYPE -ENDTEN





***********************************************************

       DO YOU WANT A VRSTEC PLOTTER SMOOTH COPY OF THE
         THE DISSPLA METAFILE THAT YOU JUST CREATED?
```

```
                         (Y OR N)
**********************************************************

-ENDTEN
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTC -NINTH
&IF .&ANS EQ .N &GOTC -START
&GOTO -EIGHT
-NINTH
EXEC DISSPOP VRSTEC
CLRSCRN
&BEGTYPE -ENDTWELVE




**********************************************************

   YOUR GRAPH(S) CAN BE PICKED UP AT THE COMPUTER CENTER.

     THE GRAPH(S) WILL BE ADDRESSED TO "POP (USER ID)".

**********************************************************

-ENDTWELVE
CP SLEEP 5 SEC
&GOTO -START
```

APPENDIX B

OPTSYSX PROGRAM LISTING

This portion of the thesis contains the OPTSYSX FORTRAN program (88 pages).

```
C***********************************************************************OPT00010
C***********************************************************************OPT00020
C************                                                ***********OPT00030
C**********                  OPTSYSX                          **********OPT00040
C********               BY JOHN G. HODEN                        ********OPT00050
C********                                                       ********OPT00060
C********    THIS PROGRAM IS A COMPLETELY INTERACTIVE           ********OPT00070
C********    OPTIMAL SYSTEMS CONTROL DESIGN/SYNTHESIS           ********OPT00080
C********    PROGRAM CAPABLE OF HANDLING VERY LARGE (80X80)+    ********OPT00090
C********    MULTIVARIABLE SYSTEMS OF LINEAR EQUATIONS.         ********OPT00100
C********                                                       ********OPT00110
C**********         VERSION 1.8   11 MAR 1984                 **********OPT00120
C************          MODIFIED BY AL DIEL                  ************OPT00130
C************         MODIFIED BY M.H. LAPTAS               ************OPT00140
C***********************************************************************OPT00150
C***********************************************************************OPT00160
      IMPLICIT REAL*8(A-H,O-Z)                                          OPT00170
C-----------------------------------------------------------------------OPT00180
      INTEGER IANS,IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDEBUG,ISET,OPT00190
     1IPSD,IYU,INORM,NS,NC,NOB,NG,IREG,IDSTAB,IRET,NROW,NCOL,ISAF,ISAH,IOPT00200
     2SAG,IGAM,IRLMAT,ZERO,ONE,ITFX                                     OPT00210
C-----------------------------------------------------------------------OPT00220
C     INCREASED DIMENSIONS -- LARGE ORDER SYSTEM.                       OPT00230
C-----------------------------------------------------------------------OPT00240
C     DIMENSION ACL(98,98),B(3,3),BA(98,98),CI(98),CR(98),CQ(98,98),    OPT00250
C    *CWI(98),CWR(98),FBGC(3,98),FBGE(98,13),G(98,98),GM(98,98),        OPT00260
C    *PRO(98,98),FC(13,13),SC(98,98),WR(196),WI(196),W11(98,98),        OPT00270
C    *W21(98,98),X(196,196),GN(98,98),HO(13,98),D1(196),D2(196),        OPT00280
C    *RM(196,196),Q(1,1),GAM(98,1),WNORM(98,98),WNORMI(98,98),          OPT00290
C    *DESTAB(98),AA(98,98),BM(98,3),CM(13,98),D(13,3),DSTORE(98,98),    OPT00300
C    *JCF(196),RES(196),AY(98,98),BB(196),CC(196),CP(98),GW(196,1),     OPT00310
C    *GV(196,13),FY(13,196),HU(3,196),PRTT(16,16)                       OPT00320
C-----------------------------------------------------------------------OPT00330
C     STANDARD PROGRAM DIMENSIONS.                                      OPT00340
C-----------------------------------------------------------------------OPT00350
      DIMENSION ACL(32,32),B(32,32),BA(32,32),CI(32),CR(32),CC(32,32),CWOPT00360
     1I(32),CWR(32),FBGC(32,32),FBGE(32,32),G(32,32),GM(32,32),PRO(32,32OPT00370
     2),RC(32,32),SC(32,32),WR(64),WI(64),W11(32,32),W21(32,32),X(64,64)OPT00380
     3,GN(32,32),HO(32,32),D1(64),D2(64),RM(64,64),Q(32,32),GAM(32,32),WOPT00390
     4NORM(32,32),WNORMI(32,32),DESTAB(32),AA(32,32),BM(32,32),CM(32,32)OPT00400
     5,D(32,32),DSTORE(32,32),JCF(64),RES(64),AY(32,32),BB(64),CC(64),CPOPT00410
     6(32),GW(64,64),GV(64,64),HY(64,64),HU(64,64),PRTT(16,16)          OPT00420
C-----------------------------------------------------------------------OPT00430
      EQUIVALENCE (W11(1,1),GW(1,1)), (W11(1,1),GV(1,1)), (W21(1,1),HY(1OPT00440
     1,1)), (W21(1,1),HU(1,1))                                          OPT00450
C-----------------------------------------------------------------------OPT00460
      COMMON /PROC/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEBOPT00470
     1UG,ISET,IREG,IPSD,IYU,INORM                                       OPT00480
```

```
C-----------------------------------------------------------------------OPT00490
      DATA IY/'Y'/,IZ/'N'/                                              OPT00500
C-----------------------------------------------------------------------OPT00510
C  SUPPRESS INDIVIDUAL UNDERFLOW, OVERFLOW, DIVIDE CHECK, AND DECIMAL  =OPT00520
C  CONVERT ERROR MESSAGES; PROVIDE SUMMARY OF ERRORS ONLY.             =OPT00530
C-----------------------------------------------------------------------OPT00540
      CALL ERRSET (207,256,-1,1,1,209)                                  OPT00550
      CALL ERRSET (215,256,-1,1)                                        OPT00560
C-----------------------------------------------------------------------OPT00570
C  INITIALIZE SAVE FLAGS.                                              =OPT00580
C-----------------------------------------------------------------------OPT00590
      ISAF=0                                                            OPT00600
      ISAG=0                                                            OPT00610
      ISAH=0                                                            OPT00620
      IGAM=0                                                            OPT00630
      ISAA=0                                                            OPT00640
      ISAB=0                                                            OPT00650
      ISET=0                                                            OPT00660
C------------------------------------------SCRNA------------------------OPT00670
5     CALL FRTCMS ('CLRSCRN ')                                          OPT00680
      WRITE (5,885)                                                     OPT00690
      CALL RDINT (IANS)                                                 OPT00700
      IF(IANS.EQ.1) GO TO 20                                            OPT00710
      IF(IANS.EQ.2) GO TO 10                                            OPT00720
      GO TO 5                                                           OPT00730
C---------------------------------------------SCRN1---------------------OPT00740
20    CALL FRTCMS ('CLRSCRN ')                                          OPT00750
      WRITE (5,890)                                                     OPT00760
      CALL RDCHAR (IANS)                                                OPT00770
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 30                       OPT00780
      GO TO 40                                                          OPT00790
30    WRITE (5,880)                                                     OPT00800
      GO TO 20                                                          OPT00810
40    CONTINUE                                                          OPT00820
      IF (IANS.EQ.IZ) GO TO 560                                         OPT00830
C---------------------------------------------SCRN2---------------------OPT00840
50    CALL FRTCMS ('CLRSCRN ')                                          OPT00850
      WRITE (5,900)                                                     OPT00860
      CALL RDCHAR (IANS)                                                OPT00870
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                       OPT00880
      GO TO 70                                                          OPT00890
60    WRITE (5,880)                                                     OPT00900
      GO TO 50                                                          OPT00910
70    CONTINUE                                                          OPT00920
      IF (IANS.EQ.IZ) GO TO 560                                         OPT00930
C---------------------------------------------ISET----------------------OPT00940
80    CALL FRTCMS ('CLRSCRN ')                                          OPT00950
      WRITE (5,910)                                                     OPT00960
```

```
          CALL RDCHAR (IANS)                                                  OPT00970
          IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 90                         OPT00980
          GO TO 100                                                           OPT00990
90        WRITE (5,880)                                                       OPT01000
          GO TO 80                                                            OPT01010
100       CONTINUE                                                            OPT01020
          IF (IANS.EQ.IY) ISET=1                                              OPT01030
C---------------------------------------------------------------------------OPT01040
C   INITIALIZE SYSTEM FLAGS.                                                 =OPT01050
C---------------------------------------------------------------------------OPT01060
10        CONTINUE                                                            OPT01070
          IRET=0                                                              OPT01080
          IOL=0                                                               OPT01090
          IQ=0                                                                OPT01100
          IR=0                                                                OPT01110
          ISS=0                                                               OPT01120
          IM=0                                                                OPT01130
          ITF1=0                                                              OPT01140
          ITF2=0                                                              OPT01150
          ITF3=0                                                              OPT01160
          IFDFW=0                                                             OPT01170
          IE=0                                                                OPT01180
          IDSTAB=0                                                            OPT01190
          IDEBUG=0                                                            OPT01200
          IPSD=0                                                              OPT01210
          IYU=0                                                               OPT01220
          INCRM=0                                                             OPT01230
          IREG=0                                                              OPT01240
          NS=0                                                                OPT01250
          NC=0                                                                OPT01260
          NOB=0                                                               OPT01270
          NG=0                                                                OPT01280
          IRDMAT=0                                                            OPT01290
C----------------------------------------------ICL-------------------------OPT01300
          CALL FRTCMS ('CLRSCRN ')                                            OPT01310
          WRITE (5,570)                                                       OPT01320
          CALL RDINT (IANS)                                                   OPT01330
          ICL=IANS-1                                                          OPT01340
          IF (IOL.EQ.2) GO TO 350                                             OPT01350
          IF (IOL.EQ.3) GO TO 200                                             OPT01360
C----------------------------------------------IQ--------------------------OPT01370
          CALL FRTCMS ('CLRSCRN ')                                            OPT01380
110       WRITE (5,580)                                                       OPT01390
          CALL RDCHAR (IANS)                                                  OPT01400
          IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 120                        OPT01410
          GO TO 130                                                           OPT01420
120       WRITE (5,880)                                                       OPT01430
          GO TO 110                                                           OPT01440
```

```
130   CONTINUE                                                          OPT01450
      IF (IANS.EQ.IY) IQ=1                                              OPT01460
      IF (IANS.EQ.IZ) IQ=0                                              OPT01470
C-----------------------------------------IR--------------------------OPT01480
      CALL FRTCMS ('CLRSCRN ')                                          OPT01490
      WRITE (5,590)                                                     OPT01500
      CALL RDINT (IANS)                                                 OPT01510
      IR=IANS-1                                                         OPT01520
C-----------------------------------------ISS-------------------------OPT01530
      CALL FRTCMS ('CLRSCRN ')                                          OPT01540
140   WRITE (5,600)                                                     OPT01550
      CALL RDCHAR (IANS)                                                OPT01560
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 150                      OPT01570
      GO TO 160                                                         OPT01580
150   WRITE (5,880)                                                     OPT01590
      GO TO 140                                                         OPT01600
160   CONTINUE                                                          OPT01610
      IF (IANS.EQ.IY) ISS=1                                             OPT01620
      IF (IANS.EQ.IZ) ISS=0                                             OPT01630
C-----------------------------------------IM--------------------------OPT01640
170   WRITE (5,610)                                                     OPT01650
      CALL RDCHAR (IANS)                                                OPT01660
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 180                      OPT01670
      GO TO 190                                                         OPT01680
180   WRITE (5,880)                                                     OPT01690
      GO TO 170                                                         OPT01700
190   CONTINUE                                                          OPT01710
      IF (IANS.EQ.IY) IM=1                                              OPT01720
      IF (IANS.EQ.IZ) IM=0                                              OPT01730
200   CONTINUE                                                          OPT01740
      IF (IOL.EQ.3) IM=1                                                OPT01750
C-----------------------------------------IFDFW-----------------------OPT01760
      CALL FRTCMS ('CLRSCRN ')                                          OPT01770
210   WRITE (5,650)                                                     OPT01780
      CALL RDCHAR (IANS)                                                OPT01790
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 220                      OPT01800
      GO TO 230                                                         OPT01810
220   WRITE (5,880)                                                     OPT01820
      GO TO 210                                                         OPT01830
230   CONTINUE                                                          OPT01840
      IF (IANS.EQ.IY) IFDFW=1                                           OPT01850
      IF (IANS.EQ.IZ) IFDFW=0                                           OPT01860
      IF (IOL.EQ.3) GO TO 350                                           OPT01870
C-----------------------------------------IDSTAB----------------------OPT01880
      CALL FRTCMS ('CLRSCRN ')                                          OPT01890
240   WRITE (5,670)                                                     OPT01900
      CALL RDCHAR (IANS)                                                OPT01910
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 250                      OPT01920
      GO TO 260                                                         OPT01930
250   WRITE (5,880)                                                     OPT01940
      GO TO 240                                                         OPT01950
260   CONTINUE                                                          OPT01960
      IF (IANS.EQ.IY) IDSTAB=1                                          OPT01970
      IF (IANS.EQ.IZ) IDSTAB=0                                          OPT01980
C---------------------------------------------IDEBUG--------------------OPT01990
270   WRITE (5,680)                                                     OPT02000
      CALL RDCHAR (IANS)                                                OPT02010
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 280                      OPT02020
      GO TO 290                                                         OPT02030
280   WRITE (5,880)                                                     OPT02040
      GO TO 270                                                         OPT02050
290   CONTINUE                                                          OPT02060
      IF (IANS.EQ.IY) IDEBUG=1                                          OPT02070
      IF (IANS.EQ.IZ) IDEBUG=0                                          OPT02080
300   CONTINUE                                                          OPT02090
C---------------------------------------------IREG----------------------OPT02100
      CALL FRTCMS ('CLRSCRN ')                                          OPT02110
320   WRITE (5,710)                                                     OPT02120
      CALL RDCHAR (IANS)                                                OPT02130
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 330                      OPT02140
      GO TO 340                                                         OPT02150
330   WRITE (5,880)                                                     OPT02160
      GO TO 320                                                         OPT02170
340   CONTINUE                                                          OPT02180
      IF (IANS.EQ.IY) IREG=1                                            OPT02190
      IF (IANS.EQ.IZ) IREG=0                                            OPT02200
350   CALL RDMATF(NS,NC,NCB,NG,ISAF,ISAG,ISAH,IGAM,ISAA,ISAB,IRDMAT)    OPT02210
      IF ((ISAF.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 352                      OPT02220
C---------------------------------------------NS------------------------OPT02230
      CALL FRTCMS ('CLRSCRN ')                                          OPT02240
      WRITE (5,720)                                                     OPT02250
      CALL RDREAL (ANSR)                                                OPT02260
      NS=IDINT(ANSR)                                                    OPT02270
352   IF (IOL.EQ.2) GO TO 360                                           OPT02280
      IF ((ISAG.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 354                      OPT02290
C---------------------------------------------NC------------------------OPT02300
      WRITE (5,730)                                                     OPT02310
      CALL RDREAL (ANSR)                                                OPT02320
      NC=IDINT(ANSR)                                                    OPT02330
354   IF ((ISAH.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 356                      OPT02340
C---------------------------------------------NCB-----------------------OPT02350
      WRITE (5,740)                                                     OPT02360
      CALL RDREAL (ANSR)                                                OPT02370
      NOB=IDINT(ANSR)                                                   OPT02380
356   IF ((IGAM.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 360                      OPT02390
C---------------------------------------------NG------------------------OPT02400
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      WRITE (5,750)                                                     OPT02410
      CALL RDREAL (ANSR)                                                OPT02420
      NG=IDINT(ANSR)                                                    OPT02430
360   CONTINUE                                                          OPT02440
      IF (IOL.EQ.2) GO TO 364                                           OPT02450
      IF (IOL.EQ.3) GO TO 310                                           OPT02460
C-----------------------------------------------IPSD--------------------OPT02470
      IF(IREG.NE.C.OR.NC.EQ.0) GO TO 310                                OPT02480
      CALL FRTCMS ('CLRSCRN ')                                          OPT02490
      WRITE (5,690)                                                     OPT02500
      CALL RDINT (IANS)                                                 OPT02510
      IPSD=IANS                                                         OPT02520
      IF (IPSD.EQ.3) IPSD=0                                             OPT02530
      IF (IPSD.EQ.0) GO TO 310                                          OPT02540
C-----------------------------------------------IYU---------------------OPT02550
      CALL FRTCMS ('CLRSCRN ')                                          OPT02560
      WRITE (5,700)                                                     OPT02570
      CALL RDINT (IANS)                                                 OPT02580
      IYU=IANS-1                                                        OPT02590
C-----------------------------------------------INCRM-------------------OPT02600
      CALL FRTCMS ('CLRSCRN ')                                          OPT02610
      WRITE (5,820)                                                     OPT02620
      CALL RDREAL (ANSR)                                                OPT02630
      INORM=IDINT(ANSR)                                                 OPT02640
310   CONTINUE                                                          OPT02650
C-----------------------------------------------ITF1--------------------OPT02660
      CALL FRTCMS ('CLRSCRN ')                                          OPT02670
      WRITE (5,620)                                                     OPT02680
      CALL RDINT (IANS)                                                 OPT02690
      ITF1=IANS-1                                                       OPT02700
      IF (IOL.EQ.3) GO TO 362                                           OPT02710
C-----------------------------------------------ITF2--------------------OPT02720
      IF(IREG.NE.1) GO TO 315                                           OPT02730
      CALL FRTCMS ('CLRSCRN ')                                          OPT02740
      WRITE (5,630)                                                     OPT02750
      CALL RDINT (IANS)                                                 OPT02760
      ITF2=IANS-1                                                       OPT02770
C-----------------------------------------------ITF3--------------------OPT02780
315   IF (IREG.NE.0 .OR. (NC.EQ.0 .OR. NG.EQ.0)) GO TO 362              OPT02790
      CALL FRTCMS ('CLRSCRN ')                                          OPT02800
      WRITE (5,640)                                                     OPT02810
      CALL RDINT (IANS)                                                 OPT02820
      ITF3=IANS-1                                                       OPT02830
C-----------------------------------------------IE----------------------OPT02840
362   CONTINUE                                                          OPT02850
      IF((ITF1+ITF2+ITF3).EQ.0) GO TO 364                               OPT02860
      CALL FRTCMS ('CLRSCRN ')                                          OPT02870
      WRITE (5,660)                                                     OPT02880
      CALL RDREAL (ANSR)                                                OPT02890
      IE=IDINT(ANSR)                                                    OPT02900
C------------------------------------------------FLAG SETTINGS----------OPT02910
394   CONTINUE                                                          OPT02920
      CALL FRTCMS ('CLRSCRN ')                                          OPT02930
      WRITE (6,760)                                                     OPT02940
      WRITE (6,770)                                                     OPT02950
      WRITE (6,780) IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDEBUG,ISETOPT02960
     1,IDSTAB                                                           OPT02970
      WRITE (6,790)                                                     OPT02980
      WRITE (6,800) IPSD,IYU,INORM,IREG,NS,NC,NOB,NG                    OPT02990
      WRITE (6,810) NS,NC,NOB,NG                                        OPT03000
C------------------------------------------------CPTGRAPH DATA FILES ---OPT03010
      ZERO = 0                                                          OPT03020
      ONE = 1                                                           OPT03030
      REWIND 10                                                         OPT03040
      ITFX = 1                                                          OPT03050
      WRITE (10,1000) ZERO,ONE,NS,NC,NOB,IE,ITFX                        OPT03060
      REWIND 1                                                          OPT03070
      ITFX = 2                                                          OPT03080
      WRITE (1,1000) ZERO,ONE,NS,NG,NOB,IE,ITFX                         OPT03090
      REWIND 4                                                          OPT03100
      ITFX = 3                                                          OPT03110
      WRITE (4,1000) ZERO,ONE,NS,NOB,NC,IE,ITFX                         OPT03120
C------------------------------------------------BEGIN CALCULATIONS-----OPT03130
      N2=2*NS                                                           OPT03140
      CALL INNER (NS,NC,NOB,NG,N2,ACL,B,BA,CI,CR,CC,CWI,CWR,D,FBGC,FBGE,OPT03150
     1G,GAM,GM,GN,HC,D1,D2,PRO,RM,RC,Q,SC,WR,WI,W11,W21,X,WNORM,WNORMI,DOPT03160
     2ESTAB,AA,BM,CM,JCF,RES,AY,BB,CC,CP,GW,GV,HY,HU,DSTORE,ISAF,ISAH,ISOPT03170
     3AG,IGAM,IRET,PRTT,NRCW,NCOL,IRDMAT,ISAA,ISAB)                     OPT03180
C-------------------------------------------------CPTGROL DATA----------OPT03190
      IF((ITF1.EQ.1).OR.(ITF1.EQ.2)) GO TO 396                          OPT03200
      END FILE 10                                                       OPT03210
      REWIND 10                                                         OPT03220
      ITFX = 1                                                          OPT03230
      WRITE (10,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                OPT03240
C-------------------------------------------------CPTGRNO DATA----------OPT03250
396   IF((ITF2.EQ.1).OR.(ITF2.EQ.2)) GO TO 397                          OPT03260
      END FILE 1                                                        OPT03270
      REWIND 1                                                          OPT03280
      ITFX = 2                                                          OPT03290
      WRITE (1,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                 OPT03300
C-------------------------------------------------OPTGRCM DATA----------OPT03310
397   IF((ITF1.EQ.3).OR.(ITF3.EQ.2)) GO TO 398                          OPT03320
      END FILE 4                                                        OPT03330
      REWIND 4                                                          OPT03340
      ITFX = 3                                                          OPT03350
      WRITE (4,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                 OPT03360
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C-----------------------------------------------------------------------OPT03370
360   IF(IRET.EQ.1) GO TO 370                                           OPT03380
      CALL WRTMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NOB,NG)              OPT03390
C------------------------------------------------IRET-------------------OPT03400
370   WRITE (5,830)                                                     OPT03410
      CALL RDCHAR (IANS)                                                OPT03420
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 380                      OPT03430
      GO TO 390                                                         OPT03440
380   WRITE (5,880)                                                     OPT03450
      GO TO 370                                                         OPT03460
390   CONTINUE                                                          OPT03470
C------------------------------------------------RESET OPGRAPH DATA FILEOPT03480
      IF(IANS.EQ.IZ) GO TO 395                                          OPT03490
      END FILE 10                                                       OPT03500
      REWIND 10                                                         OPT03510
      END FILE 1                                                        OPT03520
      REWIND 1                                                          OPT03530
      END FILE 4                                                        OPT03540
      REWIND 4                                                          OPT03550
C-----------------------------------------------------------------------OPT03560
395   IF (IANS.EQ.IY) GO TO 400                                         OPT03570
      IF (IANS.EQ.IZ) GO TO 560                                         OPT03580
C------------------------------------------------ISAF-------------------OPT03590
400   CONTINUE                                                          OPT03600
      IF (IRET.EQ.1) GO TO 10                                           OPT03610
      IF (ISET.EQ.1) GO TO 10                                           OPT03620
      CALL FRTCMS ('CLRSCRN ')                                          OPT03630
410   WRITE (5,840)                                                     OPT03640
      CALL RDCHAR (IANS)                                                OPT03650
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 420                      OPT03660
      GO TO 430                                                         OPT03670
420   WRITE (5,880)                                                     OPT03680
      GO TO 410                                                         OPT03690
430   CONTINUE                                                          OPT03700
      IF (IANS.EQ.IY) ISAF=1                                            OPT03710
      IF (IANS.EQ.IZ) ISAF=0                                            OPT03720
C------------------------------------------------ISAH-------------------OPT03730
      IF (NOB.EQ.0) GO TO 470                                           OPT03740
      CALL FRTCMS ('CLRSCRN ')                                          OPT03750
440   WRITE (5,850)                                                     OPT03760
      CALL RDCHAR (IANS)                                                OPT03770
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 450                      OPT03780
      GO TO 460                                                         OPT03790
450   WRITE (5,880)                                                     OPT03800
      GO TO 440                                                         OPT03810
460   CONTINUE                                                          OPT03820
      IF (IANS.EQ.IY) ISAH=1                                            OPT03830
      IF (IANS.EQ.IZ) ISAH=0                                            OPT03840
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470   CONTINUE                                                          OPT03850
C-----------------------------------------------ISAG--------------------OPT03860
      IF (NC.EQ.0) GO TO 510                                            OPT03870
      CALL FRTCMS ('CLRSCRN ')                                          OPT03880
480   WRITE (5,860)                                                     OPT03890
      CALL RDCHAR (IANS)                                                OPT03900
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 490                      OPT03910
      GO TO 500                                                         OPT03920
490   WRITE (5,880)                                                     OPT03930
      GO TO 480                                                         OPT03940
500   CONTINUE                                                          OPT03950
      IF (IANS.EQ.IY) ISAG=1                                            OPT03960
      IF (IANS.EQ.IZ) ISAG=0                                            OPT03970
510   CONTINUE                                                          OPT03980
C-----------------------------------------------IGAM--------------------OPT03990
      IF (NG.EQ.0) GO TO 550                                            OPT04000
      CALL FRTCMS ('CLRSCRN ')                                          OPT04010
520   WRITE (5,870)                                                     OPT04020
      CALL RDCHAR (IANS)                                                OPT04030
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 530                      OPT04040
      GO TO 540                                                         OPT04050
530   WRITE (5,880)                                                     OPT04060
      GO TO 520                                                         OPT04070
540   CONTINUE                                                          OPT04080
      IF (IANS.EQ.IY) IGAM=1                                            OPT04090
      IF (IANS.EQ.IZ) IGAM=0                                            OPT04100
550   CONTINUE                                                          OPT04110
C-----------------------------------------------ISAA--------------------OPT04120
      CALL FRTCMS ('CLRSCRN ')                                          OPT04130
551   WRITE (5,872)                                                     OPT04140
      CALL RDCHAR (IANS)                                                OPT04150
      IF ((IANS.EQ.IY).OR.(IANS.EQ.IZ)) GO TO 553                       OPT04160
      WRITE (5,880)                                                     OPT04170
      GO TO 551                                                         OPT04180
553   CONTINUE                                                          OPT04190
      IF (IANS.EQ.IY) ISAA=1                                            OPT04200
      IF (IANS.EQ.IZ) ISAA=0                                            OPT04210
C-----------------------------------------------ISAB--------------------OPT04220
      CALL FRTCMS ('CLRSCRN ')                                          OPT04230
555   WRITE (5,874)                                                     OPT04240
      CALL RDCHAR (IANS)                                                OPT04250
      IF ((IANS.EQ.IY).OR.(IANS.EQ.IZ)) GO TO 557                       OPT04260
      WRITE (5,880)                                                     OPT04270
      GO TO 555                                                         OPT04280
557   CONTINUE                                                          OPT04290
      IF (IANS.EQ.IY) ISAB=1                                            OPT04300
      IF (IANS.EQ.IZ) ISAB=0                                            OPT04310
      GO TO 10                                                          OPT04320
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C-----------------------------------------------TERMINATE----------------OPT04330
560   WRITE (5,920)                                                      OPT04340
      STOP                                                               OPT04350
C------------------------------------------------------------------------OPT04360
885   FORMAT (5X,33HIN CASE OF PROBLEMS CALL EXT 2826,///,10X,42H1  DEFIOPT04370
     1NES MATRIX EQUATIONS USED IN OPTSYS,/,15X,32HAND ALTERNATE DATA INOPT04380
     2PUT METHODS,//,10X,26H2  START INTERACTIVE INPUT,///,15X,13HENTER OPT04390
     3 1 OR 2,///,5X,59HNORMALLY TWO SUCCESSIVE NULL ENTERS TERMINATES TOPT04400
     4HE PROGRAM.)                                                      OPT04410
890   FORMAT (5X,59HOPTSYSX IS A COMPLETELY INTERACTIVE OPTIMAL SYSTEMS OPT04420
     1CONTROL,/,8X,55HPROGRAM. IT WILL SOLVE NUMEROUS CONTROL PROBLEMS OOPT04430
     2N THE,/,8X,45HFOLLOWING TYPES OF SYSTEMS CONTROL EQUATIONS:,//,15XOPT04440
     3,35HXDOT =  F&*X +  G&*U +  GAM&*(W+WO),//,20X,22HMEASUREMENT EQUAOPT04450
     4TION--,//,15X,21HZ =  H&*X +  D&*U + V,//,20X,29HREGULATOR PERFORMOPT04460
     5ANCE INDEX--,//,15X,42HJ = 1/2 * INTEGRAL (Y9* A&*Y + U9* B&*U)DT,OPT04470
     6//,20X,32HSTATE FEEDBACK GAIN DEFINITION--,//,25X,10HU = - C&*X,//OPT04480
     7,15X,45HDO YOU WISH TO CONTINUE?  TYPE "YES" OR "NO".)            OPT04490
900   FORMAT (25X,14H--DATA ENTRY--,//,5X,49HALTHOUGH OPTSYSX IS SPECIFIOPT04500
     1CALLY DESIGNED TO READ,/,5X,48HALL MATRIX DATA INTERACTIVELY, SEVEOPT04510
     2RAL ALTERNATE,/,5X,31HMETHODS ARE AVAILABLE TO USERS:,//,10X,43HMEOPT04520
     3THOD 1--THE "F","G", AND "GAMMA" MATRICES,/,13X,37HMAY BE READ FROOPT04530
     4M SEPARATE DATA FILES.,//,10X,50HMETHOD 2--THE "F","G", AND "GAMMAOPT04540
     5" MATRICES MAY BE,/,13X,45HEXPLICITLY DEFINED WITHIN SUBROUTINE "SOPT04550
     6ETUP".,//,10X,52H NOTE: IN EITHER CASE, THE USER SHOULD OBTAIN A COPT04560
     7OPY,/,17X,34HOF THE PROGRAM LISTING AND EXAMINE,/,17X,39HTHE EXAMPOPT04570
     8LES CONTAINED IN S/R "SETUP".&,//,10X,45HDO YOU WISH TO CONTINUE? OPT04580
     9 TYPE "YES" OR "NO".)                                             OPT04590
910   FORMAT (//,5X,46HDO YOU WISH TO INPUT THE "F", "G", AND "GAMMA",/,OPT04600
     110X,40HMATRICES FROM SUBROUTINE "SETUP" IAW THE,/,10X,40HMETHOD DEOPT04610
     2SCRIBED ON THE PREVIOUS SCREEN?,//,15X,19HTYPE "YES" OR "NO".)    OPT04620
570   FORMAT (25X,24HGENERAL OPTSYSX OPTIONS:,//,10X,35HOPTION 1 -- SYSTOPT04630
     1EM ANALYSIS WITHOUT,/,22X,35HOPEN-LOOP EIGENSYSTEM CALCULATIONS.,/OPT04640
     2/,10X,42HOPTION 2 -- SYSTEM ANALYSIS WITH OPEN-LOOP,/,22X,25HEIGENOPT04650
     3SYSTEM CALCULATIONS.,//,10X,39HOPTION 3 -- OPEN-LOOP EIGENSYSTEM FOPT04660
     4OUND,/,22X,23HAND PROGRAM TERMINATES.,/,22X,39H "F"-MATRIX ENTRY FOPT04670
     5OLLOWS IMMEDIATELY.&,//,10X,48HOPTION 4 -- MODAL DISTRIBUTION MATROPT04680
     6ICES COMPUTED,/,22X,37HWITHOUT FILTER OR REGULATOR SYNTHESIS,/,22XOPT04690
     7,25HOR STEADY-STATE ANALYSIS.,//,15X,30HSELECT AN OPTION: 1,2,3, OOPT04700
     8R 4.)                                                             OPT04710
580   FORMAT (//,5X,46HDO YOU DESIRE RMS VALUES OF STATE AND CONTROL?,//OPT04720
     1,10X,19HTYPE "YES" OR "NO".)                                      OPT04730
590   FORMAT (/,20X,30HOPTSYSX LQR/CLASSICAL OPTIONS:,//,10X,43HOPTION 1OPT04740
     1 -- OPTIMAL FILTER AND/OR REGULATOR,/,22X,37HSYNTHESIS WITH NO EXTOPT04750
     2ERNAL "C" OR "K",/,22X,13HMATRIX INPUT.,//,10X,43HOPTION 2 -- OPTIOPT04760
     3MAL FILTER AND/OR REGULATOR,/,22X,27HSYNTHESIS WITH EXTERNAL "C",/OPT04770
     4,22X,13HMATRIX INPUT.,//,10X,43HOPTION 3 -- OPTIMAL FILTER AND/OR OPT04780
     5REGULATOR,/,22X,27HSYNTHESIS WITH EXTERNAL "K",/,22X,13HMATRIX INPOPT04790
     6UT.,//,10X,  'OPTION 4 -- SYSTEM ANALYSIS'              ,/,22X,   OPT04800
     7          'WITH EXTERNAL "C" AND "K" MATRIX INPUT.',//,10X         OPT04810
     8,32HSELECT AN OPTICN: 1, 2, 3, OR 4.)                               OPT04820
6CC   FORMAT (//,5X,50HDC YOU WISH TO DETERMINE THE STEADY-STATE RESPONSOPT04830
     1E,/,8X,27HFCR A CONSTANT DISTURBANCE?,//,10X,19HTYPE "YES" CR "NO"OPT04840
     2.)                                                                  OPT04850
61C   FORMAT (5X,47HDO YOU WISH TO DETERMINE THE MCCAL CISTRIBUTION,/,8XOPT04860
     1,18HAND GAIN MATRICES?,//,10X,19HTYPE "YES" CR "NO".)               OPT04870
620   FORMAT (//,5X,36HOPEN-LOOP TRANSFER FUNCTICN CPTIONS:,//,10X,53HOPOPT04880
     1TION 1 -- NC OPEN-LOCP TRANSFER FUNCTICNS CCMPUTED.,//,10X,48HOPTIOPT04890
     2CN 2 -- POLES, RESIDUES, AND ZEROS COMPUTED.,//,10X,42HCPTICN 3 --OPT04900
     3 ONLY POLES AND ZERCS COMPUTED.,//,10X,45HOPTION 4 -- CNLY POLES AOPT04910
     4ND RESIDUES COMPUTED.,//,10X,32HSELECT AN CPTION: 1, 2, 3, CR 4.,/OPT04920
     5///,8X,32HIF ANALYSIS CAUSES MODAL OUTPUT,//,5X,61HPCLES AND ZEROSOPT04930
     6 MUST BE SELECTED IF YOU WISH TO USE OPTGRAPH.)                     OPT04940
630   FCRMAT (//,5X,32HNOISE TRANSFER FUNCTICN OPTICNS:,//,10X,49HCPTIONOPT04950
     1 1 -- NO NCISE TRANSFER FUNCTIONS COMPUTED.,//,10X,48HOPTION 2 -- OPT04960
     2POLES, RESICUES, AND ZEROS COMPUTED.,//,10X,42HCPTICN 3 -- CNLY POOPT04970
     3LES AND ZERCS COMPUTEC.,//,10X,45HOPTION 4 -- ONLY POLES AND RESIDOPT04980
     4LES CCMPUTEC.,//,10X,32HSELECT AN OPTICN: 1, 2, 3, CR 4.)           OPT04990
640   FCRMAT (//,5X,38HCOMPENSATOR TRANSFER FUNCTICN CPTICNS:,//,10X,49HOPT05000
     1CPTION 1 -- NC COMP. TRANSFER FUNCTIONS COMPUTEC.,//,10X,48HCPTIONOPT05010
     2 2 -- POLES, RESIDUES, AND ZEROS COMPUTED.,//,10X,42HOPTICN 3 -- OOPT05020
     3NLY POLES AND ZEROS COMPUTED.,//,10X,45HCPTICN 4 -- ONLY PCLES ANDOPT05030
     4 RESIDUES CCMPUTED.,//,15X,45H NOTE: A COMPENSATOR TRANSFER FUNCTIOPT05040
     5ON CAN BE,/,22X,33HCCMPUTED ONLY IF BOTH A REGULATOR,/,22X,26HAND OPT05050
     6FILTER ARE SYNTHESIZED,/,22X,14HAND/OR INPUT.&,//,10X,32HSELECT ANOPT05060
     7 CPTION: 1, 2, 3, CR 4.)                                            OPT05070
65C   FORMAT (//,5X,39HWILL A FEED-FORWARD DISTRIBUTICN MATRIX,/,5X,25H OPT05080
     1"D" - MATRIX& BE INPUT ?,//,15X,19HTYPE "YES" OR "NO".)             OPT05090
66C   FORMAT (/,5X,63H THIS OPTICN DETERMINES THE CRITERIA FOR CECICING OPT05100
     1WHEN A MARKCV,/,8X,58HPARAMETER IS ZERO-THE MARKOV PARAMETER INDICOPT05110
     2ATES THE ORCER,/,8X,54HOF THE NUMERATOR PCLYNCMIAL OF EACH TRANSFEOPT05120
     3R FUNCTION.,//,8X,52HALL "N" ZEROS OF THIS PCLYNOMIAL ARE PRINTED OPT05130
     4OUT ANC,/,8X,52HTHIS TEST TELLS HOW MANY EXTRA ROOTS EXIST AT Z = OPT05140
     50.,/,8X,41HLESS THAN 10.0** -IE& IS CONSICEREC ZERO.,//,8X,47H THEOPT05150
     6 DEFAULT VALUE OF THIS PARAMETER  IE& IS 6.,/,8X,28HIN OTHER WORDSOPT05160
     7,ESP = 1.0E-6.,//,10X,66HIF YOU DESIRE A DIFFERENT MARKCV CRITERIAOPT05170
     8, TYPE THE INTEGER VALUE.,//,10X,48HIF YCU DESIRE THE DEFAULT VALUOPT05180
     9E, TYPE "0"  ZERO&)                                                 OPT05190
67C   FORMAT (//,5X,61HDC YCU DESIRE TO SYNTHESIZE A STABLE FILTER  OR ROPT05200
     1EGULATOR& BY,/,8X,34HDESTABILIZING THE ORIGINAL SYSTEM?,//,12X,52HOPT05210
     2 NOTE:WORKS FOR FILTER OR REGULATOR BUT NOT FCR BOTH,/,20X,17HIN TOPT05220
     3HE SAME RUN.&,//,10X,19HTYPE "YES" OR "NO".)                        OPT05230
68C   FOPMAT (5X,53HDO YOU DESIRE TO PRINT THE EULER-LAGRANGE EIGENSYSTEOPT05240
     1M,/,8X,50HPRIOR TO CECCMPOSITION  FOR CHECKING THE PROGRAM&?,//,10OPT05250
     2X,19HTYPE "YES" OR "NO".)                                           OPT05260
69C   FORMAT (//,5X,39HPOWER SPECTRAL DENSITY  PSD& OPTION 1 :,//,10X,53OPT05270
     1HOPTION 1 -- COMPUTE THE PSD OF THE OUTPUTS AND/OF THE,/,22X,48HCOOPT05280
     2NTROLS OF THE CONTROLLED SYSTEM WHEN FORCED BY,/,22X,45HPROCESS ANOPT05290
     3D MEASUREMENT NOISE.   NOTE: BOTH A,/,22X,46HREGULATOR AND A FILTEOPT05300
     4R MUST BE RESIDENT IN THE,/,22X,28HPROGRAM TO USE THIS OPTION.&,//OPT05310
     5,10X,53HOPTION 2 -- SAME AS OPTION 1 ABOVE BUT ONLY PRINT THE,/,22OPT05320
     6X,34HRESIDUES OF EACH TRANSFER FUNCTION,/,22X,28HUSED IN THE PSD COPT05330
     7MPUTATION.,//,10X,24HOPTION 3 -- NOT DESIRED.,///,10X,29HSELECT AOPT05340
     8N OPTION: 1, 2, OR 3.)                                            OPT05350
700   FORMAT (//,5X,39HPOWER SPECTRAL DENSITY  PSD& OPTION 2 :,//,10X,350PT05360
     1HOPTION 1 -- PSD OUTPUT NOT DESIRED.,//,10X,38HOPTION 2 -- COMPUTEOPT05370
     2 ONLY OUTPUT PSD/S.,//,10X,39HOPTION 3 -- COMPUTE ONLY CONTROL PSDOPT05380
     3/S.,//,10X,50HOPTION 4 -- COMPUTE BOTH OUTPUT AND CONTROL PSD/S.,/OPT05390
     4/,15X,32HSELECT AN OPTION: 1, 2, 3, OR 4.)                        OPT05400
710   FORMAT (//,5X,39HDO YOU DESIRE REGULATOR SYNTHESIS ONLY?,//,10X,19OPT05410
     1HTYPE "YES" OR "NO".,//)                                          OPT05420
720   FORMAT (/,5X,47HENTER THE # OF STATES  NS& OF THE SYSTEM MATRIX,/,OPT05430
     15X,13H "F"-MATRIX&.)                                              OPT05440
730   FORMAT (/,5X,56HENTER THE # OF CONTROLS  NC& OF THE CONTROL SYSTEMOPT05450
     1 MODEL,/,5X,13H "G"-MATRIX&.)                                     OPT05460
740   FORMAT (/,5X,54HENTER THE # OF MEASUREMENTS OR OBSERVATIONS  NO& OOPT05470
     1FTHE,/,5X,13H "H"-MATRIX&.)                                       OPT05480
750   FORMAT (/,5X,48HENTER THE # OF PROCESS NOISE SOURCES  NG& OF THE,/OPT05490
     1,5X,17H "GAMMA"-MATRIX&.)                                         OPT05500
760   FORMAT (5X,52HFLAG/PARAMETER SETTINGS FOR THIS RUN ARE AS FOLLOWS:OPT05510
     1,/)                                                               OPT05520
770   FORMAT (1X,3HIOL,2X,2HIQ,2X,2HIR,2X,3HISS,2X,2HIM,2X,4HITF1,2X,4HIOPT05530
     1TF2,2X,4HITF3,2X,5HIFDFW,2X,2HIE,2X,6HIDEBUG,2X,4HISET,2X,6HIDSTABOPT05540
     2,/)                                                               OPT05550
780   FORMAT (1X,I2,3X,I2,3X,I2,2X,I2,3X,I2,3X,I2,4X,I2,4X,I2,4X,I2,4X,IOPT05560
     12,3X,I2,6X,I2,5X,I2,/)                                            OPT05570
790   FORMAT (1X,4HIPSD,2X,3HIYU,2X,5HINORM,2X,4HIREG,2X,2HNS,2X,2HNC,2XOPT05580
     1,3HNOB,2X,2HNG,/)                                                 OPT05590
800   FORMAT (2X,I2,3X,I2,4X,I2,5X,I2,3X,I2,2X,I2,3X,I2,2X,I2,//)       OPT05600
810   FORMAT (2X,17HORDER OF SYSTEM =,I3,//,2X,20HNUMBER OF CONTROLS =,IOPT05610
     13,//,2X,24HNUMBER OF OBSERVATIONS =,I3,//,2X,33HNUMBER OF PROCESS OPT05620
     2NOISE SOURCES =,I3,////)                                          OPT05630
820   FORMAT (5X,53HDETERMINE THE NORMALIZATION PARAMETER  INORM& FOR THOPT05640
     1E,/,5X,55HPOWER SPECTRAL DENSITY  PSD& OPTION YOU HAVE PREVIOUSLY,OPT05650
     2/,5X,52HCHOSEN. TWO PSD NORMALIZATION METHODS ARE AVAILABLE:,//,10OPT05660
     3X,54HMETHOD 1 -- PSD IS NORMALIZED BY THE I-NORM/TH PROCESS,/,21X,OPT05670
     429HNOISE MINUS "Q" INORM,INORM&.,/,21X,49H NOTE: "Q" IS AN OPTIMALOPT05680
     5 STATE WEIGHTING MATRIX.&,/,21X,34HIN THIS METHOD, INORM =0,1,...,OPT05690
     6NG.,//,10X,63HMETHOD 2 -- PSD IS NORMALIZED BY THE  INORM -NG&/TH OPT05700
     7MEASUREMENT,/,21X,39HNOISE MINUS "R" INORM - NG,INORM - NG&.,/,21XOPT05710
     8,51H NOTE: "R" IS AN OPTIMAL CONTROL WEIGHTING MATRIX.&,/,21X,44HIOPT05720
     9N THIS METHOD, INORM = NG + 1,...,NG + NOB.,//,10X,51HSELECT AN INOPT05730
     $TEGER FROM 0 - 16 REPRESENTING YOUR PSD,/,15X,27HNORMALIZATION REQOPT05740
     $UIREMENTS.,//,10X,53HIF PSD NORMALIZATION IS NOT DESIRED ENTER "0"OPT05750
     $  ZERO&.)                                                         OPT05760
```

```
830   FORMAT (5X,43HANALYSIS COMPLETE. DO YOU WANT ANOTHER RUN?,/,15X,19OPT05770
     1HTYPE "YES" OR "NO".)                                             OPT05780
840   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "F"-MATRIX FROM THE LASTOPT05790
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05800
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05810
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05820
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)           OPT05830
850   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "H"-MATRIX FROM THE LASTOPT05840
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05850
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05860
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05870
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)           OPT05880
860   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "G"-MATRIX FROM THE LASTOPT05890
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05900
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05910
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05920
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)           OPT05930
870   FORMAT (///,5X,52HDO YOU WISH TO SAVE THE "GAMMA"-MATRIX FROM THE OPT05940
     1LAST,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT05950
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT05960
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT05970
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)       OPT05980
872   FORMAT (///,5X,'DO YOU WISH TO SAVE THE "A"-MATRIX FROM THE LAST' OPT05990
     1    ,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT06000
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT06010
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT06020
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)       OPT06030
874   FORMAT (///,5X,'DO YOU WISH TO SAVE THE "B"-MATRIX FROM THE LAST' OPT06040
     1    ,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT06050
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT06060
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT06070
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)       OPT06080
880   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT06090
920   FORMAT (//,41H........OPTSYSX IS NOW TERMINATED........,//)       OPT06100
C------------------------------------------------OPTGRAPH DATA----------OPT06110
1000  FORMAT(I1,I4,5I5)                                                 OPT06120
C-----------------------------------------------------------------------OPT06130
      END                                                               OPT06140
C=======================================================================OPT06150
      SUBROUTINE SETUP (BA,G,GAM,HO,NS,NC,NG,NO)                        OPT06160
C=======================================================================OPT06170
      IMPLICIT REAL*8(A-H,O-Z)                                          OPT06180
      DIMENSION BA(NS,NS),G(NS,NC),GAM(NS,NG),HO(NC,NS)                 OPT06190
      COMMON /PROG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFCFW,IE,IDSTAB,IDEBOPT06200
     1UG,ISET,IREC,IPSD,IYU,INORM                                       OPT06210
C-----------------------------------------------------------------------OPT06220
C   FILE DEFINITIONS                                                    OPT06230
C-----------------------------------------------------------------------OPT06240
```

```
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','X29A82  ',
     1'DATA    ','A       ')
C-----------------------------------------------------------------------
C   THIS IS AN EXAMPLE OF A 83 X 84 DATA FILE X29A83 DATA A1 READ FROM
C   A USER'S DISK AND CONVERTED (FROM A "DUMMY" ARRAY NAMED 'DUM') TO A
C   SYMMETRIC ARRAY.  THE FORMAT STATEMENT MUST MATCH YOUR DISK DATA
C   FORMAT OR THE PROGRAM WILL FAIL   NOTE: ALL PROGRAM DIMENSIONS
C   MUST BE ENLARGED ACCORDINGLY FOR A SYSTEM OF THIS SIZE.
C-----------------------------------------------------------------------
C     READ (3,100)
C     READ (3,100)
      DO 20 I=1,NS
      READ (3,50) (BA(I,J),J=1,NS)
20    CONTINUE
C-----------------------------------------------------------------------
C   THESE ARE EXAMPLES OF SEVERAL POSSIBLE METHODS OF ARRAY GENERATION
C   WITHIN SUBROUTINE SETUP.THE "GAM" ARRAY WAS SET TO ZERO SINCE NO
C   "NOISE" WAS PRESENT, AND THE NON-ZERO ELEMENTS OF THE "G" ARRAY WERE
C   EXPLICITLY DEFINED. THEY COULD ALSO BE READ FROM FILES AS ABOVE.
C-----------------------------------------------------------------------
      DO 40 I=1,NS
      DO 30 J=1,NC
      GAM(I,J)=0.0D+00
      G(I,J)=0.0D+00
30    CONTINUE
40    CONTINUE
      G(82,1)= 0.1000D+00
C     G(52,1)= 0.362D+07
C     G(77,1)=-0.1591D+02
C     G(78,1)= 0.2448D+00
C     G(79,1)= 0.2448D+00
C     G(81,1)= 0.1000D+00
C-----------------------------------------------------------------------
C     READ (3,100)
C     DO 70 I=1,NS
C     READ (3,50) (G(I,J),J=1,NC)
C70   CONTINUE
C-----------------------------------------------------------------------
C   THIS IS AN EXAMPLE OF ONE POSSIBLE METHOD OF ARRAY GENERATION      =
C   WITHIN THE PROGRAM ITSELF.  FOR VERY LARGE DATA ARRAYS, THIS METHOD =
C   MAY BE PREFERABLE TO SOME USERS OVER INTERACTIVE ENTRY OF EACH     =
C   INDIVIDUAL ELEMENT.                                                =
C-----------------------------------------------------------------------
C     DO 2 I=1,11
C        DO 1 J=1,82
C             HO(I,J)    = 0.0D+00
C             HO(1,1)    = 0.11520D+00
C             HO(2,75)   = 0.5730D+02
```

```
C              HO(3,74)  = 0.1000D+01
C              HO(4,63)  = 0.5730D+02
C              HO(5,62)  = 0.1000D+01
C              HO(6,76)  = 0.5730D+02
C              HO(7,44)  = 0.5730D+02
C              HO(8,45)  = 0.5730D+02
C              HO(9,46)  = 0.5730D+02
C              HO(10,47) = 0.5730D+02
C              HO(11,48) = 0.5730D+02
C1          CONTINUE
C2      CONTINUE
C       GO TO 90
C3      CONTINUE
C------------------------------------------------------------------------
C       READ (3,100)
C       DO 90 I=1,NC
C       READ (3,50) (HO(I,J),J=1,NS)
C90     CONTINUE
        RETURN
C----------------------------------------------------------------------- 
5C      FORMAT (5E12.4)
C50     FORMAT (3(D22.15,3X))
C100    FORMAT ()
        END
C=======================================================================
        SUBROUTINE CHECK (EPS,NC,NG,NO,IRET)
C       CHECKS THE CONSISTENCY OF REQUESTED OPTIONS.                   =
C=======================================================================
        DOUBLE PRECISION EPS
        COMMON /PRCG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEB
       1UG,ISET,IREG,IPSD,IYU,INORM
C-------SET MODAL ANALYSIS WHEN OL EIGENSYS OR CL TF REQUESTED----------
        IF (IM .EQ. 1 .AND. IOL .EQ. 0) IOL=1
        IF (IOL .EQ. 3 .OR. ITF1 .NE. 0) IM=1
C---------------CHECK TO SEE IF H MATRIX INPUT--------------------------
        IF (NO .NE. 0 .OR. ICL .GE. 2) GO TO 10
        WRITE (5,90)
        IRET=1
        RETURN
10      CONTINUE
C---------------TRANSFER FUNCTION CHECKS--------------------------------
        IF (IE .EQ. 0) IE=6
        EPS=10.**(-IE)
C--------------------OPEN LOOP TF---------------------------------------
        IF (ITF1 .EQ. 0 .OR. NC .NE . 0) GO TO 20
        WRITE (5,100)
        IRET=1
        RETURN
```

```
C-----------------------COMPENSATOR TF---------------------------------------OPT07210
2C     IF (ITF3 .EC. 0) GC TO 30                                             OPT07220
       IF (IREG .EC. 0 .AND. (NC .NE. 0 .AND. NG .NE. 0)) GO TC 30           OPT07230
       WRITE (5,11C)                                                          OPT07240
       IRET=1                                                                 OPT07250
       RETURN                                                                 OPT07260
3C     CONTINUE                                                               OPT07270
C-----------------------NCISE TF---------------------------------------------OPT07280
       IF (ITF2 .EC. 0) GO TO 40                                             OPT07290
       IF (NG.NE. 0 .AND. NC .NE. 0) GO TO 40                                OPT07300
       WRITE (5,12C)                                                          OPT07310
       IRET=1                                                                 OPT07320
       RETURN                                                                 OPT07330
C-------------------DESTABILIZATION RESTRICTIONS-----------------------------OPT07340
4C     IF (IDSTAB .EQ. 0) GC TO 50                                           OPT07350
       IF (NC .EQ. 0) GO TC 50                                               OPT07360
       IF (NG .NE. 0) IREG=1                                                 OPT07370
       WRITE (5,13C)                                                          OPT07380
       IF (IREG .EC. 1) GO TO 50                                             OPT07390
       IRET=1                                                                 OPT07400
       RETURN                                                                 OPT07410
5C     CONTINUE                                                               OPT07420
C-------------------PSD INPUT------------------------------------------------OPT07430
       IF (IPSD .EC. 0) GO TO 80                                             OPT07440
       IF (IPSD .LT. 0 .OR. IPSD .GT. 3) GO TO 60                            OPT07450
       IF (IYU .LT. 0 .OR. IYU .GT. 3) GO TO 60                              OPT07460
       IF (INORM .LT. 0 .OR. INORM .GT. NG+ND) GC TC 60                      OPT07470
       GO TO 70                                                               OPT07480
6C     WRITE (5,14C)                                                          OPT07490
       IRET=1                                                                 OPT07500
       RETURN                                                                 OPT07510
7C     IF (IREG .EC. 0 .ANC. NC .NE. 0) GO TO 80                             OPT07520
       WRITE (5,15C)                                                          OPT07530
       IRET=1                                                                 OPT07540
       RETURN                                                                 OPT07550
8C     CCNTINUE                                                               OPT07560
       RETURN                                                                 OPT07570
C----------------------------------------------------------------------------OPT07580
9C     FORMAT (//,5X,49H H - MATRIX MUST BE INPUT, I.E. "NC" MUST BE > 0.OPT07590
      1,//)                                                                   OPT07600
1C0    FORMAT (//,5X,46H(G) MATRIX MUST BE INPUT, I.E. NC MUST BE > 0.,/,OPT07610
      110X,26HTO CCMPUTE OPEN LOOP T. F.,//)                                  OPT07620
110    FORMAT (//,5X,48HREGULATOR AND FILTER SYNTHESIS MUST BE REQUESTED,OPT07630
      1/,5X,44HIN THE SAME RUN TO COMPUTE COMPENSATCR T. F.,/,5X,47HI.E. OPT07640
      2IPEG MUST = 0.; "NC" AND "NG" MUST BE > C.,//)                         OPT07650
120    FORMAT (//,5X,51HNCISE T. F. CALCULATED CNLY WHEN REGULATOR DESIGNOPT07660
      1ED,/,5X,47HI.E. IREG MUST = 1.; "NC" AND "NG" MUST BE > 0.,//)        OPT07670
130    FORMAT (//,5X,47HDESTABILIZATION OPTION DESIGNED FOR A REGULATCR,/OPT07680
     1,5X,38HOR FILTER BUT NOT BOTH SIMULTANEOUSLY.,//,5X,55HIF "NG" > 0OPT07690
     2. THE REGULATOR OPTION IS AUTOMATICALLY SET ,//)                  OPT07700
140   FORMAT (//,5X,49H ********** INCONSISTENT PSD INPUT FLAGS ********OPT07710
     1,//)                                                              OPT07720
150   FORMAT (//,5X,44HBOTH A REGULATOR AND FILTER MUST BE RESIDENT,/,10OPT07730
     1X,42HTO COMPUTE THE PSD OF A CONTROLLED SYSTEM ,/,10X,42HI.E. IREGOPT07740
     2 MUST BE 0. AND "NC" MUST BE > 0.,//)                             OPT07750
      END                                                               OPT07760
C=======================================================================OPT07770
      SUBROUTINE INNER (NS,NC,NO,NG,N2,ACL,B,BA,CI,CR,CQ,CWI,CWR,D,FBGC,OPT07780
     1FBGE,G,GAM,GM,GN,HO,D1,D2,PRO,RM,RC,Q,SC,WR,WI,W11,W21,X,WNORM,WNOOPT07790
     2RMI,DESTAB,AA,BM,CM,JCF,RES,AY,BB,CC,CP,GW,GV,HY,HU,DSTORE,ISAF,ISOPT07800
     3AH,ISAG,IGAM,IRET,PRTT,NROW,NCOL,IRDMAT,ISAA,ISAB)                OPT07810
C=======================================================================OPT07820
      IMPLICIT REAL*8(A-H,O-Z)                                          OPT07830
C-----------------------------------------------------------------------OPT07840
      DIMENSION ACL(NS,NS),B(NC,NC),BA(NS,NS),CI(NS),CR(NS),CC(NS,NS),CWOPT07850
     1I(NS),CWR(NS),FBGC(NC,NS),FBGE(NS,NO),G(NS,NS),GM(NS,NS),PRO(NS,NSOPT07860
     2),RC(NO,NO),SC(NS,NS),WR(N2),WI(N2),W11(NS,NS),W21(NS,NS),X(N2,N2)OPT07870
     3,GN(NS,NS),HO(NO,NS),D1(N2),D2(N2),RM(N2,N2),C(NG,NG),D(NC,NC),GAMOPT07880
     4(NS,NG),WNORM(NS,NS),WNORMI(NS,NS),DESTAB(NS),AA(NS,NS),BM(NS,NC),OPT07890
     5CM(NO,NS),JCF(N2),RES(N2),AY(NO,NO),BB(N2),CC(N2),CP(NS),GW(N2,NG)OPT07900
     6,GV(N2,NO),HY(NO,N2),HU(NC,N2),DSTORE(NS,NS),PRTT(16,16)          OPT07910
C-----------------------------------------------------------------------OPT07920
      COMMON /PROG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEBOPT07930
     1UG,ISET,IREG,IPSD,IYL,INORM                                       OPT07940
C-----------------------------------------------------------------------OPT07950
      REAL*4 FMT(20)                                                    OPT07960
C----------------------OUTPUT OPTIONS-----------------------------------OPT07970
C---IOL=1 IF THE OPEN LOOP EIGENSYSTEM IS DESIRED--OTHERWISE IOL=0      OPT07980
C---IQ=1 IF THE RMS VALUES OF THE CONTROL AND STATE ARE TO BE FOUND     OPT07990
C---IR=0 IF OPTIMAL FILTER AND REGULATOR EIGENSYSTEMS ARE TO BE FOUND   OPT08000
C---IR=1 IF EXTERNAL C MATRIX IS SUPPLIED                               OPT08010
C---IR=2 IF EXTERNAL K IS SUPPLIED                                      OPT08020
C---IR=3 IF EXTERNAL C AND K ARE SUPPLIED                               OPT08030
C---ISS=1 IF STEADY STATE VALUES ARE TO BE DETERMINED                   OPT08040
C---IM=1 IF MODAL STATES DESIRED                                        OPT08050
C-----------------------------------------------------------------------OPT08060
      NSQ=NS*NS                                                         OPT08070
      MH=NS                                                             OPT08080
      M=N2                                                              OPT08090
      CALL CHECK (EPS,NC,NG,NO,IRET)                                    OPT08100
      IF (IRET.EQ.1) RETURN                                             OPT08110
      IF (ISET.EQ.1) GO TO 20                                           OPT08120
      CALL RDMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NC,NG,IRDMAT)         OPT08130
      CALL READF (NS,ISAF,BA)                                           OPT08140
      IF (IDSTAB.EQ.0) GO TO 10                                         OPT08150
      WRITE (5,1800)                                                    OPT08160
      CALL RDREAL (ANSR)                                                OPT08170
      DSTAB=ANSR                                                        OPT08180
      DO 10 I=1,NS                                                      OPT08190
      DESTAB(I)=DSTAB                                                   OPT08200
   10 CONTINUE                                                          OPT08210
      GO TO 30                                                          OPT08220
   20 CALL SETUP (BA,G,GAM,HO,NS,NC,NG,NO)                              OPT08230
   30 CONTINUE                                                          OPT08240
      WRITE (6,1380)                                                    OPT08250
      DO 40 I=1,NS                                                      OPT08260
   40 WRITE (6,1390) (BA(I,J),J=1,NS)                                   OPT08270
      IF (IDSTAB.EQ.0) GO TO 50                                         OPT08280
      WRITE (6,1480)                                                    OPT08290
      WRITE (6,1390) (DESTAB(I),I=1,NS)                                 OPT08300
   50 CONTINUE                                                          OPT08310
C--------------EIGENSYSTEM OF THE OPEN LOOP DYNAMICS-------------------OPT08320
      IF (IOL.EQ.0.AND.IQ.EQ.0) GO TO 90                                OPT08330
      IF (IOL.EQ.0.AND.NC.NE.0) GO TO 90                                OPT08340
      DO 60 I=1,NS                                                      OPT08350
      DO 60 J=1,NS                                                      OPT08360
   60 GN(I,J)=BA(I,J)                                                   OPT08370
      CALL BALANC (NS,NS,GN,LOW,IHIGH,D1)                               OPT08380
      CALL ORTHES (NS,NS,LOW,IHIGH,GN,D2)                               OPT08390
      CALL ORTRAN (NS,NS,LOW,IHIGH,GN,D2,SC)                            OPT08400
      CALL HQR2 (NS,NS,LOW,IHIGH,GN,CWR,CWI,SC,IERR)                    OPT08410
      IF (IERR.NE.0) CALL EREXIT (NS,GN,IERR)                           OPT08420
      CALL BALBAK (NS,NS,LOW,IHIGH,D1,NS,SC)                            OPT08430
C----------NORMALIZE AND PRINT OPEN LOOP EIGENSYSTEM-------------------OPT08440
      IWRITE=1                                                          OPT08450
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,FC,CM,OPT08460
     1NO,NS)                                                            OPT08470
C-----------------------------------------OPTGROL/OPTGRNO DATA---OPT08480
      DO 64 I = 1,NS                                                    OPT08490
         WRITE (10,2000) CWR(I), CWI(I)                                 OPT08500
         WRITE (1,2000) CWR(I), CWI(I)                                  OPT08510
   64 CONTINUE                                                          OPT08520
C-----------------------------------------------------------------------OPT08530
      IF (IOL.EQ.2) RETURN                                              OPT08540
      IF (IQ.EQ.0.OR.(NC.NE.0.OR.IDSTAB.GT.0)) GO TO 90                 OPT08550
      DO 70 I=1,NS                                                      OPT08560
      IF (CWR(I).LT.0.) GO TO 70                                        OPT08570
      WRITE (5,1490)                                                    OPT08580
      RETURN                                                            OPT08590
   70 CONTINUE                                                          OPT08600
      IF (IOL.EQ.3) GO TO 130                                           OPT08610
      DO 80 I=1,NS                                                      OPT08620
      DO 80 J=1,NS                                                      OPT08630
   80 W11(I,J)=SC(I,J)                                                  OPT08640
```

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      CALL MINV (NSQ,W11,NS,DDD,D1,D2)                                  OPT08650
 90   CONTINUE                                                          OPT08660
      IF (IDSTAB.EQ.0) GO TO 130                                        OPT08670
C---------------- FORM U * DIAG(DESTAB) * U-INV-------------------------OPT08680
      DO 100 J=1,NS                                                     OPT08690
      DO 100 I=1,NS                                                     OPT08700
 100  AA(I,J)=WNORM(I,J)*DESTAB(J)                                      OPT08710
      DO 120 I=1,NS                                                     OPT08720
      DO 120 J=1,NS                                                     OPT08730
      DDD=0.D0                                                          OPT08740
      DO 110 K=1,NS                                                     OPT08750
 110  DDD=DDD+AA(I,K)*WNORMI(K,J)                                       OPT08760
      DSTORE(I,J)=DDD                                                   OPT08770
 120  BA(I,J)=BA(I,J)+DDD                                               OPT08780
 130  CONTINUE                                                          OPT08790
      IF (NO.EQ.0) GO TO 145                                            OPT08800
      IF (ISET.EQ.1) GO TO 135                                          OPT08810
      CALL READH (NO,NS,ISAH,HO)                                        OPT08820
 135  CONTINUE                                                          OPT08830
      WRITE (6,1440)                                                    OPT08840
      DO 140 I=1,NC                                                     OPT08850
 140  WRITE (6,1390) (HO(I,J),J=1,NS)                                   OPT08860
 145  IF (IM.NE.1) GO TO 150                                            OPT08870
      CALL MODE (WNORM,HO,CM,NS,NO,NS,2)                                OPT08880
 150  CONTINUE                                                          OPT08890
      IF (IFCFW.EQ.0) GO TO 170                                         OPT08900
      CALL READD (NO,NC,D)                                              OPT08910
      WRITE (6,1470)                                                    OPT08920
      DO 160 I=1,NC                                                     OPT08930
 160  WRITE (6,1390) (D(I,J),J=1,NC)                                    OPT08940
 170  CONTINUE                                                          OPT08950
      NOB=0                                                             OPT08960
      IF (NC.EQ.0) GO TO 590                                            OPT08970
      IF (IOL.EQ.3) GO TO 270                                           OPT08980
      IF (IR.NE.1.AND.IR.NE.3) GO TO 210                                OPT08990
      IF (ISET.EQ.1) GO TO 180                                          OPT09000
      CALL READG (NS,NC,ISAG,G)                                         OPT09010
 180  CONTINUE                                                          OPT09020
      CALL READFB (NC,NS,FBGC)                                          OPT09030
      WRITE (6,1400)                                                    OPT09040
      DO 190 I=1,NS                                                     OPT09050
 190  WRITE (6,1390) (G(I,J),J=1,NC)                                    OPT09060
      IF (IM.NE.1) GO TO 200                                            OPT09070
      CALL MODE (WNORMI,G,BM,NS,NS,NC,0)                                OPT09080
 200  CONTINUE                                                          OPT09090
      GO TO 330                                                         OPT09100
 210  DO 220 I=1,NS                                                     OPT09110
      DO 220 J=1,NS                                                     OPT09120
```

```
220   RM(I+MH,J)=0.0                                                    OPT09130
      CALL READAY (NO,ISAA,AY)                                          OPT09140
      DO 240 I=1,NC                                                     OPT09150
      DO 240 J=1,NS                                                     OPT09160
      DDD=0.D0                                                          OPT09170
      DO 230 K=1,NC                                                     OPT09180
230   DDD=DDD+AY(I,K)*HO(K,J)                                           OPT09190
240   AA(I,J)=DDD                                                       OPT09200
      WRITE (6,1460)                                                    OPT09210
      DO 250 I=1,NO                                                     OPT09220
250   WRITE (6,1390) (AY(I,J),J=1,NO)                                   OPT09230
      DO 260 I=1,NS                                                     OPT09240
      DO 260 J=1,NS                                                     OPT09250
      DO 260 K=1,NC                                                     OPT09260
260   RM(I+MH,J)=RM(I+MH,J)+AA(K,I)*HO(K,J)                             OPT09270
270   IF (ISET.EQ.1) GO TO 280                                          OPT09280
      CALL READG (NS,NC,ISAG,G)                                         OPT09290
280   CONTINUE                                                          OPT09300
      IF (IOL.EQ.3) GO TO 290                                           OPT09310
      CALL READB (NC,ISAB,B)                                            OPT09320
290   WRITE (6,1400)                                                    OPT09330
      DO 300 I=1,NS                                                     OPT09340
300   WRITE (6,1390) (G(I,J),J=1,NC)                                    OPT09350
      IF (IM.NE.1) GO TO 310                                            OPT09360
      CALL MODE (WNORMI,G,BM,NS,NS,NC,0)                                OPT09370
310   CONTINUE                                                          OPT09380
      IF (IOL.EQ.3) GO TO 340                                           OPT09390
      WRITE (6,1410)                                                    OPT09400
      DO 320 I=1,NC                                                     OPT09410
320   WRITE (6,1390) (B(I,J),J=1,NC)                                    OPT09420
330   IF (ITF1.EQ.0) GO TO 350                                          OPT09430
C-----------------OPEN LOOP TRANSFER FUNCTIONS-------------------------OPT09440
340   WRITE (6,1500)                                                    OPT09450
      ITFX=1                                                            OPT09460
      CALL TF (NS,NS,NSQ,BA,AA,NC,G,BM,NO,HO,CM,IFDFW,D,BB,CC,CP,WR,WI,COPT09470
     1WR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF1,ITFX)                        OPT09480
350   IF (IOL.NE.3) GO TO 360                                           OPT09490
      IF (NG.EQ.0) RETURN                                               OPT09500
      GO TO 600                                                         OPT09510
360   CONTINUE                                                          OPT09520
      IF (IR.EQ.1.OR.IR.EQ.3) GO TO 500                                 OPT09530
C---CALCULATION OF CONTROL GAINS:FORMATION OF CONTROL HAMILTONIAN-------OPT09540
C                                                                       OPT09550
C      --                  --        ***F AND FT ARE THE OPEN LOOP      OPT09560
C     |                      |          DYNAMICS MATRIX AND TRANSPOSE   OPT09570
C     |    F      -GM*BI*GMT |       ***BI IS NCXNC CONTROL WEIGHTING   OPT09580
C     |                      |          MATRIX                          OPT09590
C     |                      |       ***A IS THE NSXNS STATE WEIGHTINGOPT09600
```

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C      |                         |                    MATRIX                        OPT09610
C      |__     -A          -FT __|                                                  OPT09620
C      ---                    ---         ***GM IS THE NSXNC CONTROL                OPT09630
C                                            DISTRIBUTION MATRIX                    OPT09640
C-----------------------------------------------------------------------------------OPT09650
      DO 370 I=1,NC                                                                 OPT09660
      DO 370 J=1,MH                                                                 OPT09670
370   PRO(I,J)=G(J,I)/B(I,I)                                                        OPT09680
      DO 380 I=1,MH                                                                 OPT09690
      DO 380 J=1,MH                                                                 OPT09700
      RM(I,J+MH)=0.D0                                                               OPT09710
      DO 380 K=1,NC                                                                 OPT09720
380   RM(I,J+MH)=RM(I,J+MH)-G(I,K)*PRO(K,J)                                         OPT09730
C-------------------2NX2N HAMILTONIAN MATRIX----------------------------------------OPT09740
C-------------------DIAGONAL BLOCKS---M11 AND M22----------------------------------OPT09750
      DO 390 I=1,MH                                                                 OPT09760
      DO 390 J=1,MH                                                                 OPT09770
      RM(I,J)=BA(I,J)                                                               OPT09780
      RM(I+MH,J+MH)=-BA(J,I)                                                        OPT09790
C-------------------------M21 BLOCK------------------------------------------------OPT09800
390   RM(I+MH,J)=-RM(I+MH,J)                                                        OPT09810
C------------------M12 BLOCK IS DEFINED IN LINE 430 ABOVE--------------------------OPT09820
400   CONTINUE                                                                      OPT09830
      IF (IDEBUG.EQ.0) GO TO 410                                                    OPT09840
      WRITE (6,1510)                                                                OPT09850
      CALL RAPRNT (M,M,M,9,RM,4,'(9(1X,1PD13.6))')                                  OPT09860
410   CALL BALANC (M,M,RM,LOW,IHIGH,D1)                                             OPT09870
      CALL ORTHES (M,M,LOW,IHIGH,RM,D2)                                             OPT09880
      CALL ORTRAN (M,M,LOW,IHIGH,RM,D2,X)                                           OPT09890
      CALL HQR2 (M,M,LOW,IHIGH,RM,WR,WI,X,IERR)                                     OPT09900
      IF (IERR .NE. 0) CALL EREXIT (M,RM,IERR)                                      OPT09910
      CALL BALBAK (M,M,LOW,IHIGH,D1,M,X)                                            OPT09920
C-------------DEBUG DIAGNOSTICS ON EULER-LAGRANGE EQUATIONS-------------------------OPT09930
      IF (IDEBUG .EQ. 0) GO TO 430                                                  OPT09940
      WRITE (6,1520)                                                                OPT09950
      DO 420 I=1,M                                                                  OPT09960
420   WRITE (6,1530) WR(I),WI(I)                                                    OPT09970
      WRITE (6,1540)                                                                OPT09980
      CALL RAPRNT (M,M,M,9,X,4,'(9(1X,1PD13.6))')                                   OPT09990
430   CONTINUE                                                                      OPT10000
      IF (IDSTAB .EQ. 1) GO TO 440                                                  OPT10010
      IF (NOB.EQ.0) WRITE (6,1550)                                                  OPT10020
      IF (NOB.NE.0) WRITE (6,1560)                                                  OPT10030
440   IF (NOB.NE. 0) GO TO 750                                                      OPT10040
      CALL RGAIN (M,NS,NC,NOB,WR,WI,X,GN,W11,RM,W21,D1,CWR,CWI,SC,MHS,D2OPT10050
     1)                                                                             OPT10060
C------------------------CHECK EIGENVECTORS----------------------------------------OPT10070
      IF (IDEBUG .EQ. 0) GO TO 450                                                  OPT10080
      WRITE (6,1570)
      CALL RAPRNT (NS,NS,NS,9,SC,4,'(9(1X,1PD13.6))')
450   CONTINUE
C------RESET FLAG AND F MATRIX FOR ITERATIVE DESTABILIZATION CASE-------
      IF (IDSTAB .EQ. 0) GO TO 470
      DO 460 I=1,NS
460   BA(I,I)=BA(I,I)-DESTAB(I)
      IR=1
470   CONTINUE
C-------------------CALCULATION OF FEEDBACK GAIN------------------------
C------------FEEDBACK GAINS--->  U = -(BINVERSE)*GT*GN&----------------
C-----------------------CALCULATE GT------------------------------------
      DO 490 I=1,NC
      DO 490 J=1,NS
      PRO(I,J)=0.D0
      DO 480 K=1,MH
480   PRO(I,J)=PRO(I,J)+G(K,I)*GN(K,J)
490   FBGC(I,J)=-PRO(I,J)/B(I,I)
      IF (IDSTAB .EQ. 1) GO TO 500
C--------NORMALIZE AND PRINT OPT. REG. CLOSED LOOP EIGENSYSTEM----------
      IWRITE=2
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,FBGC,
     1AA,NC,NS)
C----------------THE OPTIMUM FEEDBACK CONTROL GAINS---------------------
500   WRITE (6,1580)
      DO 510 I=1,NC
510   WRITE (6,1590) (FBGC(I,J),J=1,NS)
C------COMPUTE MODAL C MATRIX  OPEN LOOP U-INVERSE SAVED IN WNORMI&-----
      IF (IM .NE. 1) GO TO 530
C-----------------------------------------------------------------------
C IN COMPUTING MODAL C RECOMPUTE U OPEN LOOP SINCE WNORM USED TO STORE
C U & U-INV FOR CLOSED LOOP SYSTEMS; WNORMI USED TO SAVE U-INV OPEN LOOP
C-----------------------------------------------------------------------
      DO 520 I=1,NS
      DO 520 J=1,NS
520   WNORM(I,J)=WNORMI(I,J)
      CALL MINV (NSQ,WNORM,NS,DDD,D1,D2)
      CALL MODE (WNORM,FBGC,AA,NS,NC,NS,3)
530   CONTINUE
C---------------THE CLOSED LOOP DYNAMICS MATRIX-------------------------
      DO 550 I=1,NS
      DO 550 J=1,NS
      SUM=0.D0
      DO 540 K=1,NC
540   SUM=SUM+G(I,K)*FBGC(K,J)
550   ACL(I,J)=BA(I,J)+SUM
      WRITE (6,1600)
      CALL RAPRNT (MH,MH,MH,5,ACL,4,'(5(1X,1PD13.6))')
      IF (IR.NE.1.AND.IR.NE.3) GO TC 590                                OPT10570
      DO 560 I=1,NS                                                     OPT10580
      DO 560 J=1,NS                                                     OPT10590
  560 GN(I,J)=ACL(I,J)                                                  OPT10600
      CALL BALANC (NS,NS,GN,LOW,IHIGH,D1)                               OPT10610
      CALL ORTHES (NS,NS,LCW,IHIGH,GN,D2)                               OPT10620
      CALL ORTRAN (NS,NS,LCW,IHIGH,GN,D2,SC)                            OPT10630
      CALL HQR2 (NS,NS,LOW,IHIGH,GN,CWR,CWI,SC,IERR)                    OPT10640
      IF (IERR .NE. 0) CALL EREXIT (NS,GN,IERR)                         OPT10650
      CALL BALBAK (NS,NS,LCW,IHIGH,D1,NS,SC)                            OPT10660
C-------NORMALIZE AND PRINT CLOSED LOOP SUBOPT. REG. EIGENSYSTEM--------OPT10670
      IWRITE=3                                                          OPT10680
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNCRMI,FBGC, OPT10690
     1AA,NC,NS)                                                         OPT10700
      DO 570 I=1,NS                                                     OPT10710
      IF (CWR(I).LT.0.0) GC TO 570                                      OPT10720
      WRITE (5,1610)                                                    OPT10730
      RETURN                                                            OPT10740
  570 CCNTINUE                                                          OPT10750
      IF (IQ.NE.1) GO TO 590                                            OPT10760
      DO 580 I=1,NS                                                     OPT10770
      DO 580 J=1,NS                                                     OPT10780
  580 W11(I,J)=SC(I,J)                                                  OPT10790
      CALL MINV (NSQ,W11,NS,DDD,D1,D2)                                  OPT10800
  590 NCB=NO                                                            OPT10810
      IF ( NG .EQ. 0) RETURN                                            OPT10820
  600 IF (ISET.EQ.1) GO TO 610                                          OPT10830
      CALL READG2 (NS,NG,IGAM,GAM)                                      OPT10840
  610 CCNTINUE                                                          OPT10850
      IF (IOL .EQ. 3) GO TC 620                                         OPT10860
      CALL READQ (NG,Q)                                                 OPT10870
  620 WRITE (6,1420)                                                    OPT10880
      DO 630 I=1,NS                                                     OPT10890
  630 WRITE (6,1390) (GAM(I,J),J=1,NG)                                  OPT10900
      IF (IM.NE.1) GO TO 640                                            OPT10910
      CALL MCDE (WNORMI,GAM,AA,NS,NS,NG,1)                              OPT10920
  640 CCNTINUE                                                          OPT10930
      IF (IOL .EQ. 3) RETURN                                            OPT10940
      WRITE (6,1430)                                                    OPT10950
      DO 650 I=1,NG                                                     OPT10960
  650 WRITE (6,1390) (Q(I,J),J=1,NG)                                    OPT10970
      IF ((IC.EQ.C).AND.(NG.EQ.0)) GO TO 1260                           OPT10980
      DO 660 I=1,NG                                                     OPT10990
      DO 660 J=1,NS                                                     OPT11000
      PRO(I,J)=0.C0                                                     OPT11010
      DO 660 K=1,NG                                                     OPT11020
  660 PRO(I,J)=PRC(I,J)+Q(I,K)*GAM(J,K)                                 OPT11030
      DO 670 I=1,NS                                                     OPT11040
      DO 670 J=1,NS                                                     OPT11050
      CQ(I,J)=0.D0                                                      OPT11060
      DO 670 K=1,NG                                                     OPT11070
  670 CQ(I,J)=CQ(I,J)-GAM(I,K)*PRO(K,J)                                 OPT11080
      IF (IREG .EQ. 1) GO TO 690                                        OPT11090
C---CALCULATION OF FILTER GAINS:FORMATION OF ESTIMATION HAMILTONIAN-----OPT11100
C                                                                      =OPT11110
C    ---                     ---    ***F AND FT ARE SAME AS FOR        =OPT11120
C   |                           |      CONTROL HAMILTONIAN             =OPT11130
C   |   F           -GM*Q*GMT   |   ***Q IS NGXNG STATE DISTURBANCE    =OPT11140
C   |                           |      RCOVARIANCE                     =OPT11150
C   |                           |   ***R IS NOXNO MEASUREMENT NOISE    =OPT11160
C   |                           |      RCOVARIANCE                     =OPT11170
C   |  -HOT*RIN*HO       -FT    |   ***HO IS NOXNS MEASUREMENT MATRIX=OPT11180
C    ---                     ---    ***GM IS NSXNG STATE DISTURBANCE =OPT11190
C                                      DISTRIBUTION MATRIX             =OPT11200
C----------------------------------------------------------------------OPT11210
      CALL READR (NO,RC)                                                OPT11220
      WRITE (6,1450)                                                    OPT11230
      DO 680 I=1,NO                                                     OPT11240
  680 WRITE (6,1390) (RC(I,J),J=1,NO)                                   OPT11250
  690 IF (ITF2 .EQ. 0) GO TO 700                                        OPT11260
C-------------------NOISE TRANSFER FUNCTIONS----------------------------OPT11270
      WRITE (6,1620)                                                    OPT11280
      ITFX=2                                                            OPT11290
      IZERO=0                                                           OPT11300
      CALL TF (NS,NS,NSQ,ACL,AA,NG,GAM,BM,NO,HO,CM,IZERO,D,BB,CC,CF,WR, OPT11310
     1WI,CWR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF2,ITFX)                    OPT11320
      IF (IREG .EQ. 1) RETURN                                           OPT11330
  700 CONTINUE                                                          OPT11340
      IF (IREG .EQ. 1) GO TO 930                                        OPT11350
      IF (IR.LT.2) GO TO 710                                            OPT11360
      CALL READFE (NS,NO,FBGE)                                          OPT11370
      GO TO 810                                                         OPT11380
  710 CONTINUE                                                          OPT11390
C-----------THE MEASUREMENT MATRIX (HOT*RIN*HO===>SC--------------------OPT11400
      DO 720 I=1,NO                                                     OPT11410
      DO 720 J=1,MH                                                     OPT11420
  720 PRO(I,J)=HO(I,J)/RC(I,I)                                          OPT11430
      DO 730 I=1,MH                                                     OPT11440
      DO 730 J=1,MH                                                     OPT11450
      RM(I+MH,J)=0.D0                                                   OPT11460
      DO 730 K=1,NO                                                     OPT11470
  730 RM(I+MH,J)=RM(I+MH,J)-HO(K,I)*PRO(K,J)                            OPT11480
C---------------------------GM*Q*GMT===>CC------------------------------OPT11490
      DO 740 I=1,NS                                                     OPT11500
      DO 740 J=1,NS                                                     OPT11510
      RM(I,J)=BA(I,J)                                                   OPT11520
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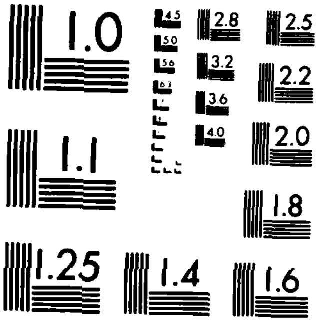
AD-A152 148 DEVELOPMENT OF GRAPHICAL POLE-ZERO ROOT-LOCUS BODE 2/3
NYQUIST AND NICHOLS RESPONSES USING THE OPTSYSX PROGRAM
(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA M H LAPTAS
UNCLASSIFIED SEP 84 F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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      RM(I+MH,J+MH)=-BA(J,I)                                            OPT11530
740   RM(I,J+NS)=CC(I,J)                                                OPT11540
      GO TO 400                                                         OPT11550
C-GO BACK TO 450 TO SET UP THE FILTER HAMILTONIAN; CALC.THE FILTER GAINSOPT11560
750   CALL RGAIN (M,NS,NC,NCB,WR,WI,X,GN,GM ,RM,W21,D1,CR,CI,PRO,MHS,D2)OPT11570
C-----------------------CHECK EIGENVECTORS-------------------------------OPT11580
      IF (IDEBUG .EQ. 0) GO TO 760                                      OPT11590
      WRITE (6,1570)                                                    OPT11600
      CALL RAPRNT (NS,NS,NS,9,PRO,4,'(9(1X,1PD13.6))')                  OPT11610
760   CONTINUE                                                          OPT11620
      IF (IDSTAB .EQ. 1) GO TO 770                                      OPT11630
C------------NORMALIZE AND PRINT OPT. ESTIMATOR EIGENSYSTEM-------------OPT11640
      IWRITE=4                                                          OPT11650
      CALL CNORM (CR,CI,PRC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HC,AA, OPT11660
     1NC,NS)                                                            OPT11670
770   DO 780 I=1,MH                                                     OPT11680
      DO 780 J=1,NO                                                     OPT11690
780   PRO(I,J)=+HC(J,I)/RC(J,J)                                         OPT11700
      DO 790 I=1,MH                                                     OPT11710
      DO 790 J=1,NO                                                     OPT11720
      FBGE(I,J)=0.D0                                                    OPT11730
      DO 790 K=1,MH                                                     OPT11740
790   FBGE(I,J)=FBGE(I,J)+GN(I,K)*PRO(K,J)                              OPT11750
      IF (IDSTAB .EQ. 1) GO TO 810                                      OPT11760
      WRITE (6,1670)                                                    OPT11770
      CALL RAPRNT (MH,MH,MH,5,GN,4,'(5(1X,1PD13.6))')                   OPT11780
      WRITE (6,1660)                                                    OPT11790
      DO 800 I=1,MH                                                     OPT11800
800   X(I,I)=DSQRT(GN(I,I))                                             OPT11810
      WRITE (6,1650) (X(I,I),I=1,MH)                                    OPT11820
810   WRITE (6,1630)                                                    OPT11830
      DO 820 I=1,MH                                                     OPT11840
820   WRITE (6,1640) (FBGE(I,J),J=1,NO)                                 OPT11850
C--------COMPUTE MODAL K MATRIX  OPEN LOOP U-INV SAVED IN WNORMI&-------OPT11860
      IF (IM .NE. 1) GO TO 830                                          OPT11870
      CALL MODE (WNORMI,FBGE,AA,MH,MH,NO,4)                             OPT11880
830   CONTINUE                                                          OPT11890
C-------RESET FLAG AND F MATRIX FOR ITERATIVE DESTABILIZATION CASE-------OPT11900
      IF (IDSTAB .EQ. 0) GO TO 850                                      OPT11910
      DO 840 I=1,NS                                                     OPT11920
      DO 840 J=1,NS                                                     OPT11930
840   BA(I,J)=BA(I,J)-DSTORE(I,J)                                       OPT11940
      IR=2                                                              OPT11950
850   CONTINUE                                                          OPT11960
      DO 870 I=1,NS                                                     OPT11970
      DO 870 J=1,NS                                                     OPT11980
      SUM=0.0                                                           OPT11990
      DO 860 K=1,NC                                                     OPT12000
```

```
860    SUM=SUM+FBGE(I,K)*HC(K,J)                                          OPT12010
870    PRO(I,J)=BA(I,J)-SUM                                               OPT12020
       WRITE (6,1650)                                                     OPT12030
       CALL RAPRNT (NS,NS,NS,5,PRO,4,'(5(1X,1PD13.6))')                   OPT12040
       IF (IR .LT. 2) GO TO 890                                           OPT12050
       CALL BALANC (NS,NS,PRO,LOW,IHIGH,D1)                               OPT12060
       CALL ORTHES (NS,NS,LOW,IHIGH,PRO,D2)                               OPT12070
       CALL ORTRAN (NS,NS,LOW,IHIGH,PRO,D2,GM)                            OPT12080
       CALL HQR2 (NS,NS,LOW,IHIGH,PRO,CR,CI,GM,IERR)                      OPT12090
       IF (IERR .NE. 0) CALL EREXIT (NS,PRO,IERR)                         OPT12100
       CALL BALBAK (NS,NS,LOW,IHIGH,D1,NS,GM)                             OPT12110
       WRITE (6,1560)                                                     OPT12120
C----------NORMALIZE AND PRINT SUBOPT. ESTIMATOR EIGENSYSTEM-----------OPT12130
       IWRITE=5                                                           OPT12140
       CALL CNORM (CR,CI,GM,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HC,AA,  OPT12150
      1NO,NS)                                                             OPT12160
       DO 880 I=1,NS                                                      OPT12170
       IF (CR(I).LT.0.0) GO TO 880                                        OPT12180
       WRITE (5,1660)                                                     OPT12190
       RETURN                                                             OPT12200
880    CONTINUE                                                           OPT12210
       GO TO 900                                                          OPT12220
890    IF (IQ.EQ.0) GO TO 1260                                            OPT12230
900    DO 910 I=1,NO                                                      OPT12240
       DO 910 J=1,MH                                                      OPT12250
       PPO(I,J)=0.D0                                                      OPT12260
       DO 910 K=1,NC                                                      OPT12270
910    PRO(I,J)=PRO(I,J)+RC(I,K)*FBGE(J,K)                                OPT12280
       DO 920 I=1,MH                                                      OPT12290
       DO 920 J=1,MH                                                      OPT12300
       CQ(I,J)=0.D0                                                       OPT12310
       DO 920 K=1,NC                                                      OPT12320
920    CQ(I,J)=CQ(I,J)-FBGE(I,K)*PRO(K,J)                                 OPT12330
930    CONTINUE                                                           OPT12340
C-----------------THE RMS STATE AND CONTROL RESPONSES-----------------OPT12350
       IR=IR+1                                                            OPT12360
       GO TO (1090,1090,940,940), IR                                      OPT12370
940    DO 950 I=1,NS                                                      OPT12380
       DO 950 J=1,NG                                                      OPT12390
       X(I,J)=0.0                                                         OPT12400
       DO 950 K=1,NG                                                      OPT12410
950    X(I,J)=X(I,J)+GAM(I,K)*Q(K,J)                                      OPT12420
       DO 970 I=1,NS                                                      OPT12430
       DO 970 J=I,NS                                                      OPT12440
       SUM=0.0                                                            OPT12450
       DO 960 K=1,NG                                                      OPT12460
960    SUM=SUM-X(I,K)*GAM(J,K)                                            OPT12470
       PPO(I,J)=SUM+CQ(I,J)                                               OPT12480
      PRO(J,I)=PRC(I,J)                                                 OPT12490
      CQ(I,J)=SUM                                                       OPT12500
      CQ(J,I)=SUM                                                       OPT12510
      W21(I,J)=GM(I,J)                                                  OPT12520
  970 W21(J,I)=GM(J,I)                                                  OPT12530
      CALL MINV (NSQ,W21,NS,DDD,D1,D2)                                  OPT12540
      CALL SCOV (NS,GM,W21,CR,CI,NS,GM,W21,CR,CI,PRC,GN)                OPT12550
      WRITE (6,1670)                                                    OPT12560
      CALL RAPRNT (MH,MH,MH,5,GN,4,'(5(1X,1PD13.6))')                   OPT12570
      WRITE (6,1680)                                                    OPT12580
      DO 980 I=1,MH                                                     OPT12590
  980 X(I,I)=DSQRT(GN(I,I))                                             OPT12600
      WRITE (6,1690) (X(I,I),I=1,MH)                                    OPT12610
      IF (IQ.EQ.0) GO TO 1260                                           OPT12620
      DO 1000 I=1,NC                                                    OPT12630
      DO 1000 J=1,NS                                                    OPT12640
      SUM=0.0                                                           OPT12650
      DO 990 K=1,NS                                                     OPT12660
  990 SUM=SUM+FBGC(I,K)*GN(K,J)                                         OPT12670
 1000 X(I,J)=SUM                                                        OPT12680
      DO 1020 I=1,NS                                                    OPT12690
      DO 1020 J=1,NS                                                    OPT12700
      SUM=0.0                                                           OPT12710
      IF (NC.EQ.0) GO TO 1020                                           OPT12720
      DO 1010 K=1,NC                                                    OPT12730
 1010 SUM=SUM+G(I,K)*X(K,J)                                             OPT12740
 1020 PRO(I,J)=CQ(I,J)+SUM                                              OPT12750
      CALL SCOV (NS,SC,W11,CWR,CWI,NS,GM,W21,CR,CI,PRO,BA)              OPT12760
      IF (NC.EQ.0) GO TO 1040                                           OPT12770
      DO 1030 I=1,NC                                                    OPT12780
      DO 1030 J=1,NS                                                    OPT12790
      W21(I,J)=0.0                                                      OPT12800
      DO 1030 K=1,NS                                                    OPT12810
 1030 W21(I,J)=W21(I,J)+FBGC(I,K)*BA(J,K)                               OPT12820
 1040 DO 1060 I=1,NS                                                    OPT12830
      DO 1060 J=1,NS                                                    OPT12840
      SUM=0.0                                                           OPT12850
      IF (NC.EQ.0) GO TO 1060                                           OPT12860
      DO 1050 K=1,NC                                                    OPT12870
 1050 SUM=SUM+G(I,K)*W21(K,J)                                           OPT12880
 1060 PRO(I,J)=SUM                                                      OPT12890
      DO 1070 I=1,NS                                                    OPT12900
      DO 1070 J=I,NS                                                    OPT12910
      PRO(I,J)=PRC(I,J)+CQ(I,J)+PRO(J,I)                                OPT12920
 1070 PRC(J,I)=PRC(I,J)                                                 OPT12930
      CALL SCOV (NS,SC,W11,CWR,CWI,NS,SC,W11,CWR,CWI,PRO,CQ)            OPT12940
      DO 1080 I=1,NS                                                    OPT12950
      DO 1080 J=I,NS                                                    OPT12960
      GM(I,J)=CQ(I,J)-BA(I,J)-BA(J,I)+GN(I,J)                           OPT12970
 1C80 GM(J,I)=GM(I,J)                                                   OPT12980
      GO TO 1100                                                        OPT12990
 1C90 CALL SCOV (NS,SC,W11,CWR,CWI,NS,SC,W11,CWR,CWI,CC,GM)             OPT13000
 1100 IF (NC.EQ.0) GO TO 1150                                           OPT13010
      CO 1120 I=1,NS                                                    OPT13020
      CO 1120 J=1,NC                                                    OPT13030
      PRO(I,J)=0.CO                                                     OPT13040
      DO 1110 K=1,NS                                                    OPT13050
 1110 PRO(I,J)=PFC(I,J)+GM(I,K)*FBGC(J,K)                               OPT13060
 1120 CCNTINUE                                                          OPT13070
      DO 1140 I=1,NC                                                    OPT13080
      CO 1140 J=1,NC                                                    OPT13090
      SC(I,J)=0.CC                                                      OPT13100
      CO 1130 K=1,NS                                                    OPT13110
 1130 SC(I,J)=SC(I,J)+FBGC(I,K)*PRO(K,J)                                OPT13120
 1140 CCNTINUE                                                          OPT13130
 1150 IF (IREG .EC. 0) GO TO 1170                                       OPT13140
      CC 1160 I=1,NS                                                    OPT13150
      DO 1160 J=1,NS                                                    OPT13160
 1160 CQ(I,J)=GM(I,J)                                                   OPT13170
      GO TO 1190                                                        OPT13180
 1170 WRITE (6,17C0)                                                    OPT13190
      CALL RAPRNT (MH,MH,MH,5,GM,4,'(5(1X,1PD13.6))')                   OPT13200
      IF (IR.GT.2) GO TO 1190                                           OPT13210
      CO 1180 I=1,MH                                                    OPT13220
      DO 1180 J=1,MH                                                    OPT13230
 1180 CQ(I,J)=GN(I,J)+GM(I,J)                                           OPT13240
 1190 CCNTINUE                                                          OPT13250
      WRITE (6,1710)                                                    OPT13260
      CALL RAPRNT (MH,MH,MH,5,CQ,4,'(5(1X,1PD13.6))')                   OPT13270
      IF (NC.EQ.C) GO TO 1210                                           OPT13280
      WRITE (6,1720)                                                    OPT13290
      CO 1200 I=1,NC                                                    OPT13300
 1200 WRITE (6,1730) (SC(I,J),J=1,NC)                                   OPT13310
 1210 DO 1220 I=1,NS                                                    OPT13320
 1220 CQ(I,I)=DSCRT(CQ(I,I))                                            OPT13330
      IF (NC.EQ.0) GO TO 1240                                           OPT13340
      CO 1230 I=1,NC                                                    OPT13350
 1230 SC(I,I)=DSCRT(SC(I,I))                                            OPT13360
 124C WRITE (6,1740)                                                    OPT13370
      CO 1250 I=1,NS                                                    OPT13380
      IF (I.LE.NC) WRITE (6,1750) CQ(I,I),SC(I,I)                       OPT13390
      IF (I.GT.NC) WRITE (6,1750) CQ(I,I)                               OPT13400
 125C CCNTINUE                                                          OPT13410
 1260 IF (ITF3 .EC. 0) GC TC 1290                                       OPT13420
C-------FORM COMPENSATOR FROM MEAS TO INPUT AND CCMPUTE TF-------------OPT13430
      DC 1280 I=1,NS                                                    OPT13440
      DO 1280 J=1,NS                                                    OPT13450
      SUM=0.D0                                                          OPT13460
      DO 1270 K=1,NC                                                    OPT13470
 1270 SUM=SUM+FBGE(I,K)*HO(K,J)                                         OPT13480
 1280 CO(I,J)=ACL(I,J)-SUM                                              OPT13490
      WRITE (6,1760)                                                    OPT13500
      ITFX=3                                                            OPT13510
      IZERO=0                                                           OPT13520
      CALL TF (NS,NS,NSQ,CC,AA,NC,FBGE,BM,NC,FBGC,CM,IZERO,D,BB,CC,CP,  OPT13530
     1WR,WI,CWR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF3,ITFX)                 OPT13540
 1290 CONTINUE                                                          OPT13550
C---------COMPUTE PSD FUNCTIONS OF THE CONTROLLED SYSTEM-------------OPT13560
      IF (IPSD .EQ. 0) GO TO 1310                                       OPT13570
      IF (IYU .LT. 3) GO TO 1300                                        OPT13580
      CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NO,HY,HU,HO,FBGE,NG,         OPT13590
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,1   ,IPSD,INORM)       OPT13600
      CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NO,HY,HY,HO,FBGE,NG,         OPT13610
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,2   ,IPSD,INORM)       OPT13620
      GO TO 1310                                                        OPT13630
 1300 CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NO,HY,HU,HO,FBGE,NG,         OPT13640
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,IYU,IPSD,INORM)        OPT13650
 1310 IF (ISS .EQ. 0) RETURN                                            OPT13660
      IF (NC .NE. 0) GO TO 1330                                         OPT13670
      DO 1320 I=1,NS                                                    OPT13680
      DO 1320 J=1,NS                                                    OPT13690
 1320 ACL(I,J)=BA(I,J)                                                  OPT13700
 1330 CONTINUE                                                          OPT13710
      CALL MINV (NSQ,ACL,NS,DDD,D1,D2)                                  OPT13720
      CALL READW (NG,WR)                                                OPT13730
      WRITE (6,1770) (WR(I),I=1,NG)                                     OPT13740
      WRITE (6,1780)                                                    OPT13750
      DO 1340 I=1,NS                                                    OPT13760
      WI(I)=0.0                                                         OPT13770
      DO 1340 J=1,NG                                                    OPT13780
 1340 WI(I)=WI(I)+GAM(I,J)*WR(J)                                        OPT13790
      DO 1360 I=1,NS                                                    OPT13800
      CR(I)=0.0                                                         OPT13810
      DO 1350 J=1,NS                                                    OPT13820
 1350 CR(I)=CR(I)-ACL(I,J)*WI(J)                                        OPT13830
 1360 WRITE (6,1390) CR(I)                                              OPT13840
      DO 1370 I=1,NC                                                    OPT13850
      CI(I)=0.0                                                         OPT13860
      DO 1370 J=1,NS                                                    OPT13870
 1370 CI(I)=CI(I)+FBGC(I,J)*CR(J)                                       OPT13880
      WRITE (6,1790) (CI(I),I=1,NC)                                     OPT13890
      RETURN                                                            OPT13900
C-----------------------------------------------------------------------OPT13910
 C670 FORMAT (2X,1P6D14.6,/,2X,6D14.6)                                  OPT13920
```

```
1380  FORMAT (//,5X,45HOPEN LOOP DYNAMICS MATRIX.................F..,//)OPT13930
1390  FORMAT (10(2X,0PD11.4))                                            OPT13940
1400  FORMAT (//,5X,45HTHE CONTROL DISTRIBUTION MATRIX...........G..,//)OPT13950
1410  FORMAT (//,5X,45HTHE CONTROL COST MATRIX....................B..,//)OPT13960
1420  FORMAT (//,5X,45HPROCESS NOISE DISTRIBUTION MATRIX.....GAMMA..,//)OPT13970
1430  FORMAT (//,5X,45HPOWER SPECTRAL DENSITY - PROCESS NOISE....Q..,//)OPT13980
1440  FORMAT (//,5X,45HMEASUREMENT SCALING MATRIX.................H..,//)OPT13990
1450  FORMAT (//,5X,45HPOWER SPECTRAL DENSITY-MEASUREMENT NOISE..R..,//)OPT14000
1460  FORMAT (//,5X,45HOUTPUT COST MATRIX........................A..,//)OPT14010
1470  FORMAT (//,5X,45HMEASUREMENT FEEDTHROUGH MATRIX............D..,//)OPT14020
1480  FORMAT (//,25X,28H....DESTABILIZATION CASE....,//,10X,39HTHE FOLLOPT14030
     1WING VALUES WILL BE ADDED DOWN,/,10X,49HTHE DIAGONAL OF THE "F" MAOPT14040
     2TRIX TO DESTABILIZE IT.,/,10X,41HOPTIMAL GAINS FOR THE DESTABILIZEOPT14050
     3D SYSTEM,/,10X,39HARE THEN USED AS FIXED SUBOPTIMAL GAINS,/,10X,28OPT14060
     4HFOR THE SYSTEM CALCULATIONS.,//)                                 OPT14070
1490  FORMAT (///43H PROGRAM TERMINATING DUE TO UNSTABLE SYSTEM)        OPT14080
1500  FORMAT (//,5X,31HOPEN LOOP TRANSFER FUNCTIONS...)                 OPT14090
1510  FORMAT (//,5X,32H EULER-LAGRANGE SYSTEM MATRIX...,//)             OPT14100
1520  FORMAT (//,5X,43HEIGENVALUES AND EIGENVECTORS OF THE 2N X 2N,/,5X,OPT14110
     145HEULER-LAGRANGE SYSTEM AFTER HQR2..............,//)             OPT14120
1530  FORMAT (1X,1P2D13.6)                                              OPT14130
1540  FORMAT (1X)                                                       OPT14140
1550  FORMAT (//,5X,41HEIGENSYSTEM OF OPTIMAL REGULATOR..........,//)    OPT14150
1560  FORMAT (//,5X,41HEIGENSYSTEM OF OPTIMAL ESTIMATOR..........,//)    OPT14160
1570  FORMAT (//,5X,39H EIGENVECTORS FROM RGAIN PRIOR TO CNORM,//)       OPT14170
1580  FORMAT (//,2X,57HTHE OPTIMAL FEEDBACK GAIN CONTROL MATRIX...C=BINVOPT14180
     1*GT*S...,//)                                                      OPT14190
1590  FORMAT (10(2X,1PD11.4))                                           OPT14200
1600  FORMAT (//,5X,45HTHE CLOSED LOOP DYNAMICS MATRIX ......F-G*C..,//)OPT14210
1610  FORMAT (///,60H   PROGRAM TERMINATING DUE TO UNSTABLE CLOSED LOOP OPT14220
     1   SYSTEM)                                                        OPT14230
1620  FORMAT (//,2X,'NOISE TRANSFER FUNCTIONS THROUGH THE CLOSED-LOOP SYOPT14240
     1STEM..',//)                                                       OPT14250
1630  FORMAT (//,5X,45HFILTER STEADY STATE GAINS................K...,//)OPT14260
1640  FORMAT (1X,2X,1P6D14.6)                                           OPT14270
1650  FORMAT (//,5X,45HTHE CLOSED LOOP FILTER DYNAMICS MATRIX IS.....,//)OPT14280
1660  FORMAT (////,43H PROGRAM TERMINATING DUE TO UNSTABLE FILTER)      OPT14290
1670  FORMAT (//,5X,45HTHE COVARIANCE OF THE ESTIMATION ERROR....P..,//)OPT14300
1680  FORMAT (//,5X,45HRMS VALUES OF THE ESTIMATION ERROR...........,//)OPT14310
1690  FORMAT ((5(1X,1PD13.6)))                                          OPT14320
1700  FORMAT (//,5X,45HTHE COVARIANCE OF THE ESTIMATE.........XHAT..,//)OPT14330
1710  FORMAT (//,5X,45HTHE STATE COVARIANCE MATRIX.....X=XHAT + P...,//)OPT14340
1720  FORMAT (//,5X,45HTHE CONTROL COVARIANCE.........U=C*XHAT*CT...,//)OPT14350
1730  FORMAT (1P6D14.6)                                                 OPT14360
1740  FORMAT (//,2X,18HSTATE RMS RESPONSE,20X,20HCONTROL RMS RESPONSE,/)OPT14370
1750  FORMAT (1X,1PD15.7,25X,D15.7)                                     OPT14380
1760  FORMAT (//,5X,50HCOMPENSATOR TRANSFER FUNCTIONS FROM MEAS. TO INPUOPT14390
     1T,/,5X,52H......................U/Z = -C*(SI-F+G*C+K*H)INV*K...,//)OPT14400
```

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1770  FORMAT (//,5X,46HSTEADY DISTURBANCE VECTOR..................W..,//OPT14410
     1,10(1X,1PD12.4/))                                                  OPT14420
1780  FORMAT (//,5X,45HSTEADY STATE VALUES OF STATE VAR. ARE........,//)OPT14430
1790  FORMAT (//,5X,47HSTEADY STATE CONTROL IS .......................,/OPT14440
     1/10(1X,1PD12.4/))                                                  OPT14450
1800  FORMAT (//,5X,49HENTER THE MAGNITUDE OF THE DESTABILIZATION VECTOROPT14460
     1,/,8X,47HTO BE ADDED DOWN THE DIAGONAL OF THE "F"-MATRIX,/,8X,18HTOPT14470
     2O DESTABILIZE IT.,//)                                              OPT14480
C-----------------------------------------------------CFGRAPH DATA------------OPT14490
2C00  FORMAT(5X,2D30.14)                                                 OPT14500
C-----------------------------------------------------------------------OPT14510
      END                                                                OPT14520
C=======================================================================OPT14530
      SUBROUTINE FAPRNT (NMAX,M,N,L,A,IDIM,FMT)                          OPT14540
      REAL*8 A(NMAX,N)                                                   OPT14550
      DIMENSION FMT(IDIM)                                                OPT14560
      NU=L                                                               OPT14570
      DO 20 NL=1,N,L                                                     OPT14580
      IF (NU.GT.N) NU=N                                                  OPT14590
      DO 10 I=1,M                                                        OPT14600
10    WRITE (6,FMT) (A(I,J),J=NL,NU)                                     OPT14610
      WRITE (6,30)                                                       OPT14620
20    NU=NU+L                                                            OPT14630
      RETURN                                                             OPT14640
30    FORMAT (1X)                                                        OPT14650
      END                                                                OPT14660
C=======================================================================OPT14670
      SUBROUTINE RGAIN (M,NS,NC,NOB,WR,WI,VF,GN,W11,TCB,W21,LT,C,CI,CT,MOPT14680
     1HS,MT)                                                             OPT14690
      IMPLICIT REAL*8 (A-H,O-Z)                                          OPT14700
      DIMENSION WR(M),WI(M),VF(M,M),GN(NS,NS)                            OPT14710
      DIMENSION W11(NS,NS),TCB(M,M),W21(NS,NS),LT(NS),MT(NS)             OPT14720
      DIMENSION C(NS),CI(NS),CT(NS,NS)                                   OPT14730
      K=1                                                                OPT14740
      KP=1                                                               OPT14750
      KN=1                                                               OPT14760
      NRZEV=0                                                            OPT14770
      NCPZEV=0                                                           OPT14780
10    IF (K.GT.M) GO TO 210                                              OPT14790
C-----------------------------------------------------------------------OPT14800
C CHECK FOR EIGVAL AT OR NEAR J-OMEGA AXIS TO INCLUDE IN E-L EIGSYS     OPT14810
C   TURN FIRST ONE POSITIVE AND SECOND ONE NEGATIVE                      OPT14820
C-----------------------------------------------------------------------OPT14830
      EIGVR=DABS(WR(K))                                                  OPT14840
      IF (EIGVR.GE.1.D-10) GO TO 60                                      OPT14850
      IF (WI(K)) 40,20,40                                                OPT14860
20    NRZEV=NRZEV+1                                                      OPT14870
      IF (NRZEV.GT.1) GO TO 30                                           OPT14880
      WR(K)=EIGVR                                                       OPT14890
      GO TO 80                                                          OPT14900
30    WR(K)=-EIGVR                                                      OPT14910
      WRITE (6,290)                                                     OPT14920
      GO TO 150                                                         OPT14930
40    NCPZEV=NCPZEV+1                                                   OPT14940
      IF (NCPZEV.GT.1) GO TO 50                                         OPT14950
      WR(K)=EIGVR                                                       OPT14960
      WR(K+1)=EIGVR                                                     OPT14970
      GO TO 110                                                         OPT14980
50    WR(K)=-EIGVR                                                      OPT14990
      WR(K+1)=-EIGVR                                                    OPT15000
      WRITE (6,300)                                                     OPT15010
      GO TO 180                                                         OPT15020
60    IF (WR(K)) 140,70,70                                              OPT15030
70    IF (WI(K)) 110,80,110                                             OPT15040
C---------------EIGENVECTOR FOR REAL EIGENVALUE,POSITIVE--------------OPT15050
80    IF (NOB.EQ.0) GO TO 100                                           OPT15060
      DO 90 J=1,M                                                       OPT15070
90    TCB(J,KP)=VF(J,K)                                                 OPT15080
100   KP=KP+1                                                           OPT15090
      K=K+1                                                             OPT15100
      GO TO 10                                                          OPT15110
C----------EIGENVECTOR FOR COMPLEX EIGENVALUE,POSITIVE REAL PART-------OPT15120
110   IF (NOB.EQ.0) GO TO 130                                           OPT15130
      DO 120 J=1,M                                                      OPT15140
      FR=VF(J,K)                                                        OPT15150
      FI=-VF(J,K+1)                                                     OPT15160
      TCB(J,KP)=FR+FI                                                   OPT15170
120   TCB(J,KP+1)=FR-FI                                                 OPT15180
130   KP=KP+2                                                           OPT15190
      K=K+2                                                             OPT15200
      GO TO 10                                                          OPT15210
140   IF (WI(K)) 180,150,180                                            OPT15220
C------------EIGENVECTOR FOR REAL EIGENVALUE,NEGATIVE REAL PART---------OPT15230
150   C(KN)=WR(K)                                                       OPT15240
      CI(KN)=WI(K)                                                      OPT15250
      IF (NOB.NE.0) GO TO 170                                           OPT15260
      KNS=KN+NS                                                         OPT15270
      DO 160 J=1,M                                                      OPT15280
160   TCB(J,KNS)=VF(J,K)                                                OPT15290
170   KN=KN+1                                                           OPT15300
      K=K+1                                                             OPT15310
      GO TO 10                                                          OPT15320
C----------EIGENVECTOR FOR COMPLEX EIGENVALUE,NEGATIVE REAL PART------OPT15330
180   RR=WR(K)                                                          OPT15340
      RI=WI(K)                                                          OPT15350
      C(KN)=RR                                                          OPT15360
      C(KN+1)=RR                                                        OPT15370
      CI(KN)=RI                                                         OPT15380
      CI(KN+1)=-RI                                                      OPT15390
      IF (NOB.NE.0) GO TO 200                                           OPT15400
      KNS=KN+NS                                                         OPT15410
      DO 190 J=1,M                                                      OPT15420
      FR=VF(J,K)                                                        OPT15430
      FI=-VF(J,K+1)                                                     OPT15440
      TCB(J,KNS)=FR+FI                                                  OPT15450
  190 TCB(J,KNS+1)=FR-FI                                                OPT15460
  200 KN=KN+2                                                           OPT15470
      K=K+2                                                             OPT15480
      GO TO 10                                                          OPT15490
  210 CONTINUE                                                          OPT15500
      IF (NOB.NE.0) GO TO 240                                           OPT15510
C--------------------------FORMATION OF W11-----------------------------OPT15520
      DO 220 I=1,NS                                                     OPT15530
      DO 220 J=1,NS                                                     OPT15540
      W11(I,J)=TCB(I,J+NS)                                              OPT15550
  220 CT(I,J)=W11(I,J)                                                  OPT15560
C--------------------------FORMATION OF W21-----------------------------OPT15570
      DO 230 I=1,NS                                                     OPT15580
      DO 230 J=1,NS                                                     OPT15590
  230 W21(I,J)=TCB(I+NS,J+NS)                                           OPT15600
  240 IF (NOB.EQ.0) GO TO 260                                           OPT15610
      DO 250 I=1,NS                                                     OPT15620
      DO 250 J=1,NS                                                     OPT15630
      W21(I,J)=-TCB(I,J)                                                OPT15640
  250 W11(I,J)=TCB(I+NS,J)                                              OPT15650
  260 CONTINUE                                                          OPT15660
C----------------------------INVERT W11---------------------------------OPT15670
      NSQ=NS*NS                                                         OPT15680
      CALL MINV (NSQ,W11,NS,DETC,LT,MT)                                 OPT15690
C----------------------CALCULATE THE RGAIN MATRIX-----------------------OPT15700
      DO 270 IL=1,NS                                                    OPT15710
      DO 270 JL=1,NS                                                    OPT15720
      GN(IL,JL)=0.D0                                                    OPT15730
      DO 270 KL=1,NS                                                    OPT15740
  270 GN(IL,JL)=GN(IL,JL)+W21(IL,KL)*W11(KL,JL)                         OPT15750
      IF (NOB.EQ.0) RETURN                                              OPT15760
      DO 280 I=1,NS                                                     OPT15770
      DO 280 J=1,NS                                                     OPT15780
  280 CT(I,J)=W11(J,I)                                                  OPT15790
      RETURN                                                            OPT15800
C-----------------------------------------------------------------------OPT15810
  290 FORMAT (1X,51H EULER-LAGRANGE EQUATIONS HAVE A REAL EIGENVALUE AT,OPT15820
     114H OR NEAR ZERO./)                                               OPT15830
  300 FORMAT (1X,49H EULER-LAGRANGE EQUATIONS HAVE A COMPLEX PAIR OF ,40OPT15840
     1HEIGENVALUES AT OR NEAR THE J-OMEGA AXIS.)                        OPT15850
      END                                                               OPT15860
C=======================================================================OPT15870
      SUBROUTINE MINV (NSQ,A,N,D,L,M)                                   OPT15880
      IMPLICIT REAL*8 (A-H,O-Z)                                         OPT15890
      DIMENSION A(NSQ),L(N),M(N)                                        OPT15900
      DOUBLE PRECISION A,D,BIGA,HOLD                                    OPT15910
      NM=N*N                                                            OPT15920
      D=1.0D0                                                           OPT15930
      NK=-N                                                             OPT15940
      DO 180 K=1,N                                                      OPT15950
      NK=NK+N                                                           OPT15960
      L(K)=K                                                            OPT15970
      M(K)=K                                                            OPT15980
      KK=NK+K                                                           OPT15990
      BIGA=A(KK)                                                        OPT16000
      DO 20 J=K,N                                                       OPT16010
      IZ=N*(J-1)                                                        OPT16020
      DO 20 I=K,N                                                       OPT16030
      IJ=IZ+I                                                           OPT16040
      IF (DABS(BIGA)-DABS(A(IJ))) 10,20,20                              OPT16050
   10 BIGA=A(IJ)                                                        OPT16060
      L(K)=I                                                            OPT16070
      M(K)=J                                                            OPT16080
   20 CONTINUE                                                          OPT16090
C-----------------------------INTERCHANGE ROWS--------------------------OPT16100
      J=L(K)                                                            OPT16110
      IF (J-K) 50,50,30                                                 OPT16120
   30 KI=K-N                                                            OPT16130
      DO 40 I=1,N                                                       OPT16140
      KI=KI+N                                                           OPT16150
      HOLD=-A(KI)                                                       OPT16160
      JI=KI-K+J                                                         OPT16170
      A(KI)=A(JI)                                                       OPT16180
   40 A(JI)=HOLD                                                        OPT16190
C-----------------------------INTERCHANGE COLUMNS-----------------------OPT16200
   50 I=M(K)                                                            OPT16210
      IF (I-K) 80,80,60                                                 OPT16220
   60 JP=N*(I-1)                                                        OPT16230
      DO 70 J=1,N                                                       OPT16240
      JK=NK+J                                                           OPT16250
      JI=JP+J                                                           OPT16260
      HOLD=-A(JK)                                                       OPT16270
      A(JK)=A(JI)                                                       OPT16280
   70 A(JI)=HOLD                                                        OPT16290
C------------------------DIVIDE COLUMN BY MINUS PIVOT-------------------OPT16300
C--------------------(VALUE OF PIVOT ELEMENT IS CONTAINED IN BIGA)------OPT16310
   80 IF (BIGA) 100,90,100                                              OPT16320
```

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90     D=0.0D0                                                                  OPT16330
       RETURN                                                                   OPT16340
100    DO 120 I=1,N                                                             OPT16350
       IF (I-K) 110,120,110                                                     OPT16360
110    IK=NK+I                                                                  OPT16370
       A(IK)=A(IK)/(-BIGA)                                                      OPT16380
120    CONTINUE                                                                 OPT16390
C---------------------------REDUCE MATRIX--------------------------------------OPT16400
       DO 150 I=1,N                                                             OPT16410
       IK=NK+I                                                                  OPT16420
       HOLD=A(IK)                                                               OPT16430
       IJ=I-N                                                                   OPT16440
       DO 150 J=1,N                                                             OPT16450
       IJ=IJ+N                                                                  OPT16460
       IF (I-K) 130,150,130                                                     OPT16470
130    IF (J-K) 140,150,140                                                     OPT16480
140    KJ=IJ-I+K                                                                OPT16490
       A(IJ)=HOLD*A(KJ)+A(IJ)                                                   OPT16500
150    CONTINUE                                                                 OPT16510
C--------------------------DIVIDE ROW BY PIVOT---------------------------------OPT16520
       KJ=K-N                                                                   OPT16530
       DO 170 J=1,N                                                             OPT16540
       KJ=KJ+N                                                                  OPT16550
       IF (J-K) 160,170,160                                                     OPT16560
160    A(KJ)=A(KJ)/BIGA                                                         OPT16570
170    CONTINUE                                                                 OPT16580
C---------------------------PRODUCT OF PIVOTS-----------------------------------OPT16590
       D=D*BIGA                                                                 OPT16600
C-----------------------REPLACE PIVOT BY RECIPROCAL-----------------------------OPT16610
       A(KK)=(1.0D0)/BIGA                                                       OPT16620
180    CONTINUE                                                                 OPT16630
C--------------------FINAL ROW AND COLUMN INTERCHANGE---------------------------OPT16640
       K=N                                                                      OPT16650
190    K=(K-1)                                                                  OPT16660
       IF (K) 260,260,200                                                       OPT16670
200    I=L(K)                                                                   OPT16680
       IF (I-K) 230,230,210                                                     OPT16690
210    JQ=N*(K-1)                                                               OPT16700
       JR=N*(I-1)                                                               OPT16710
       DO 220 J=1,N                                                             OPT16720
       JK=JQ+J                                                                  OPT16730
       HOLD=A(JK)                                                               OPT16740
       JI=JR+J                                                                  OPT16750
       A(JK)=-A(JI)                                                             OPT16760
220    A(JI)=HOLD                                                               OPT16770
230    J=M(K)                                                                   OPT16780
       IF (J-K) 190,190,240                                                     OPT16790
240    KI=K-N                                                                   OPT16800
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      DO 250 I=1,N                                                      OPT16810
      KI=KI+N                                                           OPT16820
      HOLD=A(KI)                                                        OPT16830
      JI=KI-K+J                                                         OPT16840
      A(KI)=-A(JI)                                                      OPT16850
250   A(JI)=HOLD                                                        OPT16860
      GO TO 190                                                         OPT16870
260   K=0                                                               OPT16880
      RETURN                                                            OPT16890
      END                                                               OPT16900
C=======================================================================OPT16910
      SUBROUTINE SCOV (NL,WL,WLI,VL1,VL2,NR,WR,WRI,VR1,VR2,Q,X)         OPT16920
      REAL*8 VL1(NL),VL2(NL),WL(NL,NL),WLI(NL,NL),X(NL,NR),Q(NL,NR),    OPT16930
     1   VR1(NR),VR2(NR),WR(NR,NR),WRI(NR,NR)                           OPT16940
      REAL*8 A,B,C,D,K1,K2,K3,K4                                        OPT16950
10    DO 20 I=1,NL                                                      OPT16960
      DO 20 J=1,NR                                                      OPT16970
      X(I,J)=0.                                                         OPT16980
      DO 20 II=1,NL                                                     OPT16990
20    X(I,J)=X(I,J)+WLI(I,II)*Q(II,J)                                   OPT17000
      DO 40 I=1,NL                                                      OPT17010
      DO 40 J=1,NR                                                      OPT17020
      Q(I,J)=0.                                                         OPT17030
      DO 30 JJ=1,NR                                                     OPT17040
30    Q(I,J)=Q(I,J)+X(I,JJ)*WRI(J,JJ)                                   OPT17050
40    CONTINUE                                                          OPT17060
      I=1                                                               OPT17070
50    IF (VL2(I)) 60,110,60                                             OPT17080
60    J=1                                                               OPT17090
70    IF (VR2(J)) 80,90,80                                              OPT17100
80    A=VL1(I)+VR1(J)                                                   OPT17110
      B=-2.*VL2(I)*VR2(J)                                               OPT17120
      C=A**2+VL2(I)**2+VR2(J)**2                                        OPT17130
      D=C**2-B**2                                                       OPT17140
      K1=A*C/D                                                          OPT17150
      K2=-(VR2(J)*C+VL2(I)*B)/D                                         OPT17160
      K3=-(VR2(J)*B+VL2(I)*C)/D                                         OPT17170
      K4=-A*B/D                                                         OPT17180
      I1=I+1                                                            OPT17190
      J1=J+1                                                            OPT17200
      X(I,J)=+K1*Q(I,J)+K2*Q(I,J1)+K3*Q(I1,J)+K4*Q(I1,J1)               OPT17210
      X(I,J1)=-K2*Q(I,J)+K1*Q(I,J1)-K4*Q(I1,J)+K3*Q(I1,J1)              OPT17220
      X(I1,J)=-K3*Q(I,J)-K4*Q(I,J1)+K1*Q(I1,J)+K2*Q(I1,J1)              OPT17230
      X(I1,J1)=+K4*Q(I,J)-K3*Q(I,J1)-K2*Q(I1,J)+K1*Q(I1,J1)             OPT17240
      J=J+2                                                             OPT17250
      GO TO 100                                                         OPT17260
90    A=VR1(J)+VL1(I)                                                   OPT17270
      B=A**2+VL2(I)**2                                                  OPT17280
      K1=A/B                                                            OPT17290
      K2=VL2(I)/B                                                       OPT17300
      X(I,J)=K1*C(I,J)-K2*C(I+1,J)                                      OPT17310
      X(I+1,J)=K2*Q(I,J)+K1*Q(I+1,J)                                    OPT17320
      J=J+1                                                             OPT17330
100   IF (J.LE.NR) GO TO 70                                             OPT17340
      I=I+2                                                             OPT17350
      GO TO 160                                                         OPT17360
110   J=1                                                               OPT17370
120   IF (VR2(J)) 130,140,130                                           OPT17380
130   A=VR1(J)+VL1(I)                                                   OPT17390
      B=A**2+VR2(J)**2                                                  OPT17400
      K1=A/B                                                            OPT17410
      K2=VR2(J)/B                                                       OPT17420
      X(I,J)=K1*C(I,J)-K2*C(I,J+1)                                      OPT17430
      X(I,J+1)=K2*Q(I,J)+K1*Q(I,J+1)                                    OPT17440
      J=J+2                                                             OPT17450
      GO TO 150                                                         OPT17460
140   X(I,J)=Q(I,J)/(VR1(J)+VL1(I))                                     OPT17470
      J=J+1                                                             OPT17480
150   IF (J.LE.NR) GO TO 120                                            OPT17490
      I=I+1                                                             OPT17500
160   IF (I.LE.NL) GO TO 50                                             OPT17510
      DO 170 I=1,NL                                                     OPT17520
      DO 170 J=1,NR                                                     OPT17530
      Q(I,J)=0.                                                         OPT17540
      DO 170 II=1,NL                                                    OPT17550
170   Q(I,J)=Q(I,J)+WL(I,II)*X(II,J)                                    OPT17560
      DO 190 I=1,NL                                                     OPT17570
      DO 190 J=1,NR                                                     OPT17580
      X(I,J)=0.                                                         OPT17590
      DO 180 JJ=1,NR                                                    OPT17600
180   X(I,J)=X(I,J)+Q(I,JJ)*WR(J,JJ)                                    OPT17610
190   CONTINUE                                                          OPT17620
      RETURN                                                            OPT17630
      END                                                               OPT17640
C=======================================================================OPT17650
      SUBROUTINE MODE (WNORM,G,GNORM,NS,N1,N2,ICON)                     OPT17660
C                                                                      =OPT17670
C  WNORM  TRANSFORMATION MATRIX U OR U-INV                             =OPT17680
C  NS     NO. OF STATE                                                 =OPT17690
C  NC     NO.  OF INPUTS OR OUTPUTS                                    =OPT17700
C  ICON  CONTROL FLAG TO INDICATE WHICH TRANSFORMATION                 =OPT17710
C         0 =   MCCAL G                                                =OPT17720
C         1 =   MCCAL GAMMA                                            =OPT17730
C         2 =   MCCAL H                                                =OPT17740
C         3 =   MCCAL C                                                =OPT17750
C         4 =   MCCAL K                                                =OPT17760
```

```
C        5 =  CONTROL EIGENVECTOR MATRIX                                  =OPT17770
C        6 =  MEASUREMENT EIGENVECTOR MATRIX                              =OPT17780
C=========================================================================OPT17790
      IMPLICIT REAL*8(A-H,O-Z)                                            OPT17800
      DIMENSION WNORM(NS,NS),G(N1,N2),GNORM(N1,N2)                        OPT17810
      DO 10 I=1,N1                                                        OPT17820
      DO 10 J=1,N2                                                        OPT17830
10    GNORM(I,J)=0.                                                       OPT17840
      IPOINT=ICON+1                                                       OPT17850
      GO TO (20,20,90,90,20,90,90), IPOINT                                OPT17860
20    DO 30 J=1,N2                                                        OPT17870
      DO 30 I=1,NS                                                        OPT17880
      DO 30 K=1,NS                                                        OPT17890
30    GNORM(I,J)=GNORM(I,J)+WNORM(I,K)*G(K,J)                             OPT17900
      GO TO (40,70,90,90,80), IPOINT                                      OPT17910
40    WRITE (6,170)                                                       OPT17920
50    DO 60 I=1,NS                                                        OPT17930
60    WRITE (6,230) (GNORM(I,J),J=1,N2)                                   OPT17940
      RETURN                                                              OPT17950
70    WRITE (6,180)                                                       OPT17960
      GO TO 50                                                            OPT17970
80    WRITE (6,240)                                                       OPT17980
      GO TO 50                                                            OPT17990
90    DO 100 J=1,NS                                                       OPT18000
      DO 100 I=1,N1                                                       OPT18010
      DO 100 K=1,NS                                                       OPT18020
100   GNORM(I,J)=GNORM(I,J)+G(I,K)*WNORM(K,J)                             OPT18030
      GO TO (110,110,110,120,110,130,140), IPOINT                         OPT18040
110   WRITE (6,190)                                                       OPT18050
      GO TO 150                                                           OPT18060
120   WRITE (6,200)                                                       OPT18070
      GO TO 150                                                           OPT18080
130   WRITE (6,210)                                                       OPT18090
      GO TO 150                                                           OPT18100
140   WRITE (6,220)                                                       OPT18110
150   DO 160 I=1,N1                                                       OPT18120
160   WRITE (6,230) (GNORM(I,J),J=1,NS)                                   OPT18130
      RETURN                                                              OPT18140
C-------------------------------------------------------------------------OPT18150
170   FORMAT (//,5X,45HMODAL CONTROL DISTRIBUTION MATRIX......TI*G..,//)OPT18160
180   FORMAT (//,5X,50HMODAL PROCESS NOISE DISTRIBUTION MATRIX...TI*GAM.OPT18170
     1.,//)                                                               OPT18180
190   FORMAT (//,5X,45HMODAL MEASUREMENT SCALING MATRIX...H(BAR)*T..,//)OPT18190
200   FORMAT (//,5X,45HTHE MODAL CONTROL GAINS...............C*T..,//)OPT18200
210   FORMAT (//,5X,45HCONTROL EIGENVECTOR MATRIX..............C*M..,//)OPT18210
220   FORMAT (//,5X,45HMEASUREMENT EIGENVECTOR MATRIX.....H(BAR)*M..,//)OPT18220
230   FORMAT (1X,(2X,1P6D14.6))                                           OPT18230
240   FORMAT (//,5X,45HMODAL FILTER STEADY STATE GAINS.......TI*K..,//)OPT18240
```

```
      END                                                                OPT18250
C=======================================================================OPT18260
      SUBROUTINE CNORM (WZ,WY,VEC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HOPT18270
     1O,CM,N1,N2)                                                        OPT18280
C                                                                       =OPT18290
C         WZ(I)       REAL PART OF I-TH EIGENVALUE                      =OPT18300
C                                                                       =OPT18310
C         WY(I)       COMPLEX PART OF I-TH EIGENVALUE                   =OPT18320
C                                                                       =OPT18330
C         VEC         MATRIX OF RIGHT EIGENVECTORS STORED IN REAL FORM  =OPT18340
C                       FROM HQR2                                       =OPT18350
C         NS          NO. OF STATES                                     =OPT18360
C                                                                       =OPT18370
C         IWRITE      FLAG TO CONTROL FORMATS FOR DIFFERENT EIGENSYSTEMS=OPT18380
C                                                                       =OPT18390
C         WNORM       NORMALIZED MATRIX U OF RIGHT EIGENVECTORS STORED  =OPT18400
C                       BY COLUMNS IN REAL FORM                         =OPT18410
C         WNORMI      U-INVERSE 2*CONGUGATE OF LEFT EIGENVECTORS        =OPT18420
C                         STORED BY ROW IN REAL FORM                    =OPT18430
C         NSQ,DDD,D1,D2 - ARGUMENTS PASSED TO MINV                      =OPT18440
C=======================================================================OPT18450
      IMPLICIT REAL*8 (A-H,O-Z)                                          OPT18460
      REAL*8 FIELD,COMMA,SEMCOL,RIGHT,FMT                                OPT18470
      DIMENSION WZ(NS),WY(NS),VEC(NS,NS),WNORM(NS,NS),WNORMI(NS,NS),STOROPT18480
     1E(6),D1(NS),D2(NS),FMT(14),HO(N1,N2),CM(N1,N2)                     OPT18490
      DATA FIELD/5HE12.5/,COMMA/5H,',',/,SEMCOL/5H,':',/,RIGHT/1H)/,FMT/OPT18500
     16H(1X,1P,13*1H /,SEMEND/4H,':'/                                    OPT18510
C----------NORMALIZE COMPLEX EIGENVECTORS BY LARGEST ELEMENT-----------OPT18520
      KK=0                                                               OPT18530
      LR=0                                                               OPT18540
      LC=0                                                               OPT18550
      DO 50 K=1,NS                                                       OPT18560
      IF (KK.EQ.1) GO TO 40                                              OPT18570
      IF (DABS(WY(K)).LT.1.D-10) GO TO 50                                OPT18580
      LC=LC+1                                                            OPT18590
      EMAX=0.D0                                                          OPT18600
      DO 20 I=1,NS                                                       OPT18610
      CMOD=VEC(I,K)**2+VEC(I,K+1)**2                                     OPT18620
      IF (CMOD-EMAX) 20,10,10                                            OPT18630
   10 EMAX=CMOD                                                          OPT18640
      M=I                                                                OPT18650
   20 CONTINUE                                                           OPT18660
      VMR=VEC(M,K)                                                       OPT18670
      VMI=VEC(M,K+1)                                                     OPT18680
      DO 30 I=1,NS                                                       OPT18690
      VR=VEC(I,K)                                                        OPT18700
      VI=VEC(I,K+1)                                                      OPT18710
      VECRN=(VR*VMR+VI*VMI)/EMAX                                         OPT18720
```

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          VECIN=(-VR*VMI+VI*VMR)/EMAX                                      OPT18730
          WNORM(I,K)=VECRN                                                 OPT18740
          WNORM(I,K+1)=VECIN                                               OPT18750
   30     CONTINUE                                                         OPT18760
          KK=1                                                             OPT18770
          GO TO 50                                                         OPT18780
   40     KK=0                                                             OPT18790
   50     CONTINUE                                                         OPT18800
C-----------NORMALIZE REAL EIGENVECTORS BY THE TOTAL LENGTH-----------OPT18810
          DO 80 K=1,NS                                                     OPT18820
          IF (DABS(WY(K)).GE.1.D-10) GO TO 80                              OPT18830
          LR=LR+1                                                          OPT18840
          REMOD=0.D0                                                       OPT18850
          DO 60 I=1,NS                                                     OPT18860
   60     REMOD=VEC(I,K)**2+REMOD                                          OPT18870
          RMOD=DSQRT(REMOD)                                                OPT18880
          DO 70 I=1,NS                                                     OPT18890
          RVEC=VEC(I,K)/RMOD                                               OPT18900
          WNORM(I,K)=RVEC                                                  OPT18910
   70     CONTINUE                                                         OPT18920
   80     CONTINUE                                                         OPT18930
          GO TO (90,100,110,120,130), IWRITE                               OPT18940
   90     WRITE (6,320)                                                    OPT18950
          GO TO 140                                                        OPT18960
  100     WRITE (6,330)                                                    OPT18970
          GO TO 140                                                        OPT18980
  110     WRITE (6,340)                                                    OPT18990
          GO TO 140                                                        OPT19000
  120     WRITE (6,350)                                                    OPT19010
          GO TO 140                                                        OPT19020
  130     WRITE (6,360)                                                    OPT19030
  140     KK=0                                                             OPT19040
          NPRTW=0                                                          OPT19050
          NFMTW=1                                                          OPT19060
          DO 180 I=1,NS                                                    OPT19070
          IF (KK.EQ.1) GO TO 170                                           OPT19080
          IF (DABS(WY(I)).GT.1.D-10) KK=1                                  OPT19090
C----PRINT OUT NO MORE THAN 6 WORDS, NOT SEPARATING COMPLEX EIGVAL------OPT19100
          IF (NPRTW.LT.5.OR.(NPRTW.EQ.5.AND.KK.EQ.0)) GO TO 150            OPT19110
          FMT(NFMTW+1)=RIGHT                                               OPT19120
          WRITE (6,FMT) (STORE(J),J=1,NPRTW)                               OPT19130
          NPRTW=0                                                          OPT19140
          NFMTW=1                                                          OPT19150
  150     NPRTW=NPRTW+1                                                    OPT19160
          NFMTW=NFMTW+1                                                    OPT19170
          IF (KK.EQ.1) GO TO 160                                           OPT19180
          STORE(NPRTW)=WZ(I)                                               OPT19190
          FMT(NFMTW)=FIELD                                                 OPT19200
```

```
      NFMTW=NFMTW+1
      FMT(NFMTW)=SEMCOL
      GO TO 180
160   STORE(NPRTW)=WZ(I)
      FMT(NFMTW)=FIELD
      FMT(NFMTW+1)=COMMA
      STORE(NPRTW+1)=WY(I)
      FMT(NFMTW+2)=FIELD
      FMT(NFMTW+3)=SEMCOL
      NFMTW=NFMTW+3
      NPRTW=NPRTW+1
      GO TO 180
170   KK=0
180   CONTINUE
      FMT(NFMTW)=SEMEND
      FMT(NFMTW+1)=RIGHT
      WRITE (6,FMT) (STORE(J),J=1,NPRTW)
      IF (IWRITE.NE.1) GO TO 190
      WRITE (6,370)
      GO TO 200
190   WRITE (6,380)
200   CALL RAPRNT (NS,NS,NS,6,WNORM,4,'(6(1X,1PD13.6))')
      GO TO (230,210,210,220,220), IWRITE
210   CALL MODE (WNORM,HO,CM,NS,N1,N2,5)
      GO TO 230
220   CALL MODE (WNORM,HO,CM,NS,N1,N2,6)
230   GO TO (240,250,260,270,280), IWRITE
240   WRITE (6,390)
      GO TO 290
250   WRITE (6,400)
      GO TO 290
260   WRITE (6,410)
      GO TO 290
270   WRITE (6,420)
      GO TO 290
280   WRITE (6,430)
C-----------------SAVE U-INVERSE OPEN LOOP IN WNORMI-----------------
290   IF (IWRITE .GT. 1) GO TO 310
      DO 300 I=1,NS
      DO 300 J=1,NS
300   WNORMI(I,J)=WNORM(I,J)
      CALL MINV (NSQ,WNORMI,NS,DDD,D1,D2)
      CALL RAPRNT (NS,NS,NS,6,WNORMI,4,'(6(1X,1PD13.6))')
      RETURN
310   CALL MINV (NSQ,WNORM,NS,DDD,D1,D2)
      CALL RAPRNT (NS,NS,NS,6,WNORM,4,'(6(1X,1PD13.6))')
      RETURN
C--------------------------------------------------------------------
```

```
320    FORMAT (//5X,42HOPEN LOOP EIGENVALUES..........DET(SI-F)..,//)
330    FORMAT (//5X,46HC-LOOP OPTIMAL REG. E-VALUES...DET(SI-F+G*C)..,//)
340    FORMAT (//5X,46HC-LOOP SUBOPT. REG. E-VALUES...DET(SI-F+G*C)..,//)
350    FORMAT (//5X,46HC-LOOP OPTIMAL EST. E-VALUES...DET(SI-F+K*H)..,//)
360    FORMAT (//5X,46HC-LOOP SUBOPT. EST. E-VALUES...DET(SI-F+K*H)..,//)
370    FORMAT (//5X,46HOPEN LOOP RIGHT EIGENVECTOR MATRIX.......T....,//)
380    FORMAT (//5X,46HC-LOOP RIGHT EIGENVECTOR MATRIX..........M....,//)
390    FORMAT (//5X,46HOPEN LOOP LEFT EIGENVECTOR MATRIX......T-INV..,//)
400    FORMAT (//5X,46HC-LOOP OPT. REG. LEFT E-VECTOR MATRIX..M-INV..,//)
410    FORMAT (//5X,46HC-LOOP SUBOPT-REG. LEFT E-VECTOR MATRIX..M-INV,//)
420    FORMAT (//5X,46HC-LOOP OPT. FILTER LEFT E-VECTOR MATRIX..M-INV,//)
430    FORMAT (//5X,51HC-LOOP SUBOPT. FILTER LEFT E-VECTOR MATRIX..M-INV.
      1.,//)
       END
C===========================================================================
       SUBROUTINE TF (N,NM,NSQ,A,AA,M,B,BM,L,C,CM,IFDFW,D,BB,CC,CP,
      1        EVR,EVI,PR,PI,SC,JCF,RES,D1,D2,DDD,EPS,ITF,ITFX)
       IMPLICIT REAL*8(A-H,O-Z)
       DIMENSION A(N,N),AA(N,N),B(N,M),BM(N,M),C(L,N),CM(L,N),D(L,M),BB(N
      1),CC(N),CP(N),EVR(N),EVI(N),PR(N),PI(N),SC(N,N),JCF(N),RES(N),D1(N
      2),D2(N)
C--SAVE COMPUTATION ON OL AND CL SYS WITH MODAL WORK DONE IN OPTSYS-----
       IF (ITFX .EQ. 1) GO TO 50
       IF (ITFX .EQ. 2) GO TO 10
       CALL POLES (N,NM,A,AA,M,B,L,C,PR,PI,D1,D2,JCF,SC)
C---------------COMPUTE MODAL MATRICES FOR RESIDUES---------------------
10     DO 20 I=1,N
       DO 20 J=1,N
20     AA(I,J)=SC(I,J)
       DO 30 I=1,L
       DO 30 J=1,N
       CM(I,J)=0.D0
       DO 30 K=1,N
30     CM(I,J)=CM(I,J)+C(I,K)*AA(K,J)
       CALL MINV (NSQ,AA,N,DDD,D1,D2)
       DO 40 I=1,N
       DO 40 J=1,M
       BM(I,J)=0.D0
       DO 40 K=1,N
40     BM(I,J)=BM(I,J)+AA(I,K)*B(K,J)
50     CONTINUE
       DO 60 I=1,M
       DO 60 J=1,L
       IF (ITF .NE. 3) CALL ZEROS (I,J,IFDFW,N,NM,A,AA,M,B,L,C,D,BB,CC,CP
      1,EVR,EVI,D1,D2,EPS,ITFX)
       IF (ITF .NE. 2) CALL RESID (I,J,N,JCF,M,BM,L,CM,PR,PI,RES,BB,CC,1)
60     CONTINUE
       RETURN
      END
C=======================================================================
      SUBROUTINE POLES (N,NM,A,AA,M,B,L,C,EVR,EVI,D1,D2,JCF,SC)
      IMPLICIT REAL*8(A-H,C-Z)
      DIMENSION A(N,N),AA(N,N),B(N,M),C(L,N),EVR(N),EVI(N),D1(N),D2(N),J
     1CF(N),SC(N,N)
      DO 10 I=1,N
      DO 10 J=1,N
10    AA(I,J)=A(I,J)
      CALL BALANC (NM,N,AA,LOW,IHIGH,D1)
      CALL ORTHES (NM,N,LOW,IHIGH,AA,D2)
      CALL ORTRAN (NM,N,LOW,IHIGH,AA,D2,SC)
      CALL HQR2 (NM,N,LOW,IHIGH,AA,EVR,EVI,SC,IERR)
      IF (IERR .NE. 0) GO TO 30
      CALL BALBAK (NM,N,LOW,IHIGH,D1,N,SC)
      WRITE (6,40)
      DO 20 I=1,N
C--------------------------------------------OPTGROM DATA-----------
      WRITE (4,2000) EVR(I),EVI(I)
C-------------------------------------------------------------------
20    WRITE (6,50) EVR(I),EVI(I)
      RETURN
30    WRITE (5,60)
      RETURN
C-------------------------------------------------------------------
40    FORMAT (///,28H TF DENOMINATOR EIGENVALUES:,/)
50    FORMAT (/,2X,3H  (,F13.6,4H)+J(,F13.6,1H))
60    FORMAT (35H FAILURE IN HQR2, CALCULATING POLES)
C--------------------------------------------OPTGROM DATA-----------
2000  FORMAT(5X,2D30.14)
C-------------------------------------------------------------------
      END
C===================================================================
      SUBROUTINE ZEROS (K1,K2,IFDFW,N,NM,A,AA,M,B,L,C,D,BB,CC,CP,EVR,EVI
     1,     D1,D2,EPS,ITFX)
      IMPLICIT REAL*8(A-H,C-Z)
      DIMENSION A(N,N),AA(N,N),B(N,M),C(L,N),D(L,M),BB(N),CC(N),CP(N),EV
     1R(N),EVI(N),D1(N),D2(N)
      DOUBLE PRECISION SCL,DABS
C-----------------------------------OPGRAPH DATA -------------------
      IF(ITFX.EQ.1) IFL = 10
      IF(ITFX.EQ.2) IFL = 1
      IF(ITFX.EQ.3) IFL = 4
C-------------------------------------------------------------------
      DO 10 I=1,N
      BB(I)=B(I,K1)
      CC(I)=C(K2,I)
      DO 10 J=1,N
```

```
10     AA(I,J)=A(I,J)                                                   OPT20650
       WRITE (6,90) K1,K2                                               OPT20660
       IF (IFDFW .EQ. 0) GO TO 20                                       OPT20670
       H=D(K2,K1)                                                       OPT20680
       IF (DABS(H).LE.EPS) GO TO 20                                     OPT20690
       JJ=N                                                             OPT20700
       GO TO 50                                                         OPT20710
20     NN=N-1                                                           OPT20720
       DO 30 I=1,NN                                                     OPT20730
       H=SCL(N,BB,CC)                                                   OPT20740
       CALL CCOMP (N,NM,AA,CC,CP)                                       OPT20750
       IF (DABS(H).GT.EPS) GO TO 40                                     OPT20760
30     CONTINUE                                                         OPT20770
       H=SCL(N,BB,CC)                                                   OPT20780
       WRITE (6,100) H                                                  OPT20790
C-----------------------------------OPGRAPH DATA FOR "0" ORDER---------OPT20800
          KK=ITFX                                                       OPT20810
          WRITE (IFL,300) KK,K2,K1                                      OPT20820
          ORDER = 0.0                                                   OPT20830
          WRITE (IFL,301) ORDER,H                                       OPT20840
C-----------------------------------------------------------------------OPT20850
       GO TO 70                                                         OPT20860
40     JJ=N-I                                                           OPT20870
50     WRITE (6,110) JJ,H                                               OPT20880
C-----------------------------------OPGRAPH DATA -----------------------OPT20890
          KK=ITFX                                                       OPT20900
          WRITE (IFL,300) KK,K2,K1                                      OPT20910
          ORDER = FLOAT(JJ)                                             OPT20920
          WRITE (IFL,301) ORDER,H                                       OPT20930
C-----------------------------------------------------------------------OPT20940
       CALL ACOMP (N,NM,AA,BB,CC,H)                                     OPT20950
       CALL BALANC (NM,N,AA,LOW,IHIGH,D1)                               OPT20960
       CALL ORTHES (NM,N,LOW,IHIGH,AA,D2)                               OPT20970
       CALL HQR (NM,N,LOW,IHIGH,AA,EVR,EVI,IERR)                        OPT20980
       IF (IERR .NE. 0) GO TO 80                                        OPT20990
       WRITE (6,120)                                                    OPT21000
       DO 60 I=1,N                                                      OPT21010
60     WRITE (6,130) EVR(I),EVI(I)                                      OPT21020
C-----------------------------------OPGRAPH DATA -----------------------OPT21030
          WRITE (IFL,302) K2,K1                                         OPT21040
       DO 63 LL = 1,N                                                   OPT21050
63        WRITE (IFL,301) EVR(LL),EVI(LL)                               OPT21060
C-----------------------------------------------------------------------OPT21070
70     RETURN                                                           OPT21080
80     WRITE (5,140)                                                    OPT21090
       RETURN                                                           OPT21100
C-----------------------------------------------------------------------OPT21110
90     FORMAT (///,17H TF FOR INPUT NO.,I3,15H AND OUTPUT NO.,I3,1H:)   OPT21120
```

```
1CC    FORMAT (//,5X,27HNO FINITE ZEROS.  TF GAIN =,E12.4)               OPT21130
110    FORMAT (/,3X,20HORDER OF NUMERATOR =,I3,9X,9HTF GAIN =,E12.4)      OPT21140
120    FORMAT (/,3X,57HNUMERATOR EIGENVALUES (INCLUDING EXTRANEOUS ZERO VOPT21150
      1ALUES):)                                                          OPT21160
130    FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H))                          OPT21170
140    FORMAT (52H FAILURE IN HQR CALCULATING TRANSFER FUNCTION ZEROES)  OPT21180
C------------------------------------------------OPGRAPH DATA-----------OPT21190
300    FORMAT(5X,2I5)                                                    OPT21200
3C1    FORMAT(5X,2E30.14)                                                OPT21210
3C2    FORMAT(5X,2I5)                                                    OPT21220
C-----------------------------------------------------------------------OPT21230
       END                                                               OPT21240
C=======================================================================OPT21250
       SUBROUTINE ACOMP (N,NM,A,B,C,H)                                   OPT21260
       REAL*8 A,B,C,H                                                    OPT21270
       DIMENSION A(NM,N),B(N),C(N)                                       OPT21280
       DO 10 I=1,N                                                       OPT21290
       DO 10 J=1,N                                                       OPT21300
10     A(I,J)=A(I,J)-B(I)*C(J)/H                                         OPT21310
       RETURN                                                            OPT21320
       END                                                               OPT21330
C=======================================================================OPT21340
       SUBROUTINE CCOMP (N,NM,A,C,CC)                                    OPT21350
       REAL*8 A,C,CC                                                     OPT21360
       DIMENSION A(NM,N),C(N),CC(N)                                      OPT21370
       DO 10 I=1,N                                                       OPT21380
       CC(I)=0.                                                          OPT21390
       DO 10 J=1,N                                                       OPT21400
10     CC(I)=CC(I)+C(J)*A(J,I)                                           OPT21410
       DO 20 I=1,N                                                       OPT21420
2C     C(I)=CC(I)                                                        OPT21430
       RETURN                                                            OPT21440
       END                                                               OPT21450
C=======================================================================OPT21460
       FUNCTION SCL (N,B,C)                                              OPT21470
       REAL*8 B,C,SCL                                                    OPT21480
       DIMENSION B(N),C(N)                                               OPT21490
       SCL=0.                                                            OPT21500
       DO 10 I=1,N                                                       OPT21510
1C     SCL=SCL+C(I)*B(I)                                                 OPT21520
       RETURN                                                            OPT21530
       END                                                               OPT21540
C=======================================================================OPT21550
       SUBROUTINE RESID (K1,K2,N,JCF,M,BM,L,CM,PR,PI,RES,BB,CC,IPT)      OPT21560
       IMPLICIT REAL*8(A-H,O-Z)                                          OPT21570
       DIMENSION JCF(N),BM(N,M),CM(L,N),PR(N),PI(N),RES(N),BB(N),CC(N),PROPT21580
      1T(4)                                                              OPT21590
       DATA SN/8H*SIN(B*T/,R1/8H        */,R2/8HEXP(A*T)/,SD/1H)/        OPT21600
      DATA ZERO/0.D0/,T1/4H*T**/,BLANK/8H        /,CS/8H*COS(B*T/         OPT21610
C--------------TEMPORARY MOD TILL JCF IS CALCULATED----------------------OPT21620
      DO 10 I=1,N                                                        OPT21630
10    JCF(I)=0                                                           OPT21640
C------------------------TEMPORARY MOD-----------------------------------OPT21650
      IF (IPT .EQ. 1) WRITE (6,170)                                      OPT21660
      DO 20 I=1,N                                                        OPT21670
      BB(I)=BM(I,K1)                                                     OPT21680
20    CC(I)=CM(K2,I)                                                     OPT21690
C---------------------LOOP THROUGH THE POLES-----------------------------OPT21700
      I=0                                                                OPT21710
30    I=I+1                                                              OPT21720
      IF (I .GT. N) GO TO 160                                            OPT21730
      IF (JCF(I) .EQ. 1) GO TO 60                                        OPT21740
      IF (DABS(PI(I)) .LT. 1.D-10) GO TO 50                              OPT21750
C---------COMPUTE SIMPLE COMPLEX POLE RESIDUES AND PRINT BOTH-----------OPT21760
      RES(I)=CC(I)*BB(I)+CC(I+1)*BB(I+1)                                 OPT21770
      RES(I+1)=CC(I)*BB(I+1)-CC(I+1)*BB(I)                               OPT21780
      IF (IPT .EQ. 0) GO TO 40                                           OPT21790
      PRT(1)=BLANK                                                       OPT21800
      PRT(2)=R2                                                          OPT21810
      IF (PI(I) .EQ. 0.D0) PRT(2)=BLANK                                  OPT21820
      PRT(3)=CS                                                          OPT21830
      PRT(4)=ED                                                          OPT21840
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                    OPT21850
      I=I+1                                                              OPT21860
      PRT(3)=SN                                                          OPT21870
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                    OPT21880
      GO TO 30                                                           OPT21890
40    I=I+1                                                              OPT21900
      GO TO 30                                                           OPT21910
50    CONTINUE                                                           OPT21920
C---------------COMPUTE SIMPLE REAL POLE RESIDUE-------------------------OPT21930
      RES(I)=CC(I)*BB(I)                                                 OPT21940
      IF (IPT .EQ. 0) GO TO 30                                           OPT21950
      PRT(1)=R1                                                          OPT21960
      PRT(2)=R2                                                          OPT21970
      PRT(3)=BLANK                                                       OPT21980
      PRT(4)=BLANK                                                       OPT21990
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                    OPT22000
      GO TO 30                                                           OPT22010
C----------LOOK AHEAD TO DETERMINE SIZE OF THE JORDAN BLOCK-------------OPT22020
60    K=1                                                                OPT22030
      KT=N-I                                                             OPT22040
      DO 70 J=I,KT                                                       OPT22050
      IF (JCF(J) .EQ. 0) GO TO 80                                        OPT22060
70    K=K+1                                                              OPT22070
80    CONTINUE                                                           OPT22080
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      IF (DABS(PI(I)) .LT. 1.D-10) GO TO 110                            OPT22090
C---------COMPUTE REPEATED COMPLEX POLE AND PRINT CUT ALL FCUR-----------OPT22100
      K=1                                                               OPT22110
      RES(I)=CC(I)*BB(I)+CC(I+1)*BB(I+1)+CC(I+2)*BB(I+2)+CC(I+3)*BB(I+3)OPT22120
      RES(I+1)=CC(I)*BB(I+1)-CC(I+1)*BB(I)+CC(I+2)*BB(I+3)-CC(I+3)*BB(I+OPT22130
     12)                                                                OPT22140
      RES(I+2)=CC(I)*BB(I+3)+CC(I+1)*BB(I+2)                            OPT22150
      RES(I+3)=CC(I)*BB(I+3)-CC(I+1)*BB(I+2)                            OPT22160
      IF (IPT .EQ. 0) GO TC 100                                         OPT22170
      PRT(1)=R1                                                         OPT22180
      PRT(2)=R2                                                         OPT22190
      IF (DABS(PR(I)) .GT. 1.D-10) GO TO 90                             OPT22200
      PRT(1)=BLANK                                                      OPT22210
      PRT(2)=BLANK                                                      OPT22220
9C    PRT(3)=CS                                                         OPT22230
      PRT(4)=ED                                                         OPT22240
      WRITE (6,18C) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT22250
      PRT(3)=SN                                                         OPT22260
      I=I+1                                                             OPT22270
      WRITE (6,18C) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT22280
      PRT(1)=T1                                                         OPT22290
      PRT(2)=R2                                                         OPT22300
      IF (DABS(PR(I)) .LT. 1.D-10) PRT(2)=BLANK                         OPT22310
      PRT(3)=CS                                                         OPT22320
      I=I+1                                                             OPT22330
      WRITE (6,19C) PR(I),PI(I),RES(I),PRT(1),K,(PRT(J),J=2,4)          OPT22340
      PRT(3)=SN                                                         OPT22350
      I=I+1                                                             OPT22360
      WRITE (6,19C) PR(I),PI(I),RES(I),PRT(1),K,(PRT(J),J=2,4)          OPT22370
      GO TO 30                                                          OPT22380
1CC   I=I+3                                                             OPT22390
      GO TO 30                                                          OPT22400
C----CCMPUTE REPEATED REAL PCLE RESIDUE AND PRINT CUT ALL K CF THEM-----OPT22410
110   CONTINUE                                                          OPT22420
      KT=I+K-1                                                          OPT22430
      NN=0                                                              OPT22440
      DO 130 J=I,KT                                                     OPT22450
      NN=NN+1                                                           OPT22460
      RES(J)=ZERC                                                       OPT22470
      DO 120 JJ=J,KT                                                    OPT22480
12C   RES(J)=RES(J)+BB(JJ)*CC(JJ-NN+1)                                  OPT22490
130   CCNTINUE                                                          OPT22500
      IF (IPT .EC. 0) GO TC 150                                         OPT22510
      NN=0                                                              OPT22520
      PRT(1)=T1                                                         OPT22530
      PRT(2)=R2                                                         OPT22540
      PRT(3)=BLANK                                                      OPT22550
      PPT(4)=BLANK                                                      OPT22560
      DO 140 J=I,KT                                                     OPT22570
      WRITE (6,190) PR(J),PI(J),RES(J),PRT(1),NN,(PRT(JJ),JJ=2,4)       OPT22580
140   NN=NN+1                                                           OPT22590
      GO TO 30                                                          OPT22600
150   I=KT                                                              OPT22610
      GO TO 30                                                          OPT22620
160   CONTINUE                                                          OPT22630
      RETURN                                                            OPT22640
C-----------------------------------------------------------------------OPT22650
170   FORMAT (//,3X,22HRESIDUES AT THE POLES:/,T16,9HP O L E S,T41,15HR OPT22660
     1E S I D U E S,/,T9,7HREAL(A),T26,7HIMAG(B))                       OPT22670
180   FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H),4X,1H(,F13.6,1H),3A8,A1)  OPT22680
190   FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H),4X,1H(,F13.6,1H),A4,I2,2X,OPT22690
     12A8,A1)                                                           OPT22700
      END                                                               OPT22710
C=======================================================================OPT22720
      SUBROUTINE BALANC (NM,N,A,LOW,IGH,SCALE)                          OPT22730
      INTEGER I,J,K,L,M,N,JJ,NM,IGH,LOW,IEXC                            OPT22740
      REAL*8 A(NM,N),SCALE(N)                                           OPT22750
      REAL*8 C,F,G,R,S,B2,RADIX                                         OPT22760
      REAL*8 DABS                                                       OPT22770
      LOGICAL NOCONV                                                    OPT22780
      DATA RADIX/Z4210000000000000/                                     OPT22790
C-----------------------------------------------------------------------OPT22800
      B2=RADIX*RADIX                                                    OPT22810
      K=1                                                               OPT22820
      L=N                                                               OPT22830
      GO TO 60                                                          OPT22840
C------------IN-LINE PROCEDURE FOR ROW AND COLUMN EXCHANGE-------------OPT22850
10    SCALE(M)=J                                                        OPT22860
      IF (J .EQ. M) GO TO 40                                            OPT22870
      DO 20 I=1,L                                                       OPT22880
      F=A(I,J)                                                          OPT22890
      A(I,J)=A(I,M)                                                     OPT22900
      A(I,M)=F                                                          OPT22910
20    CONTINUE                                                          OPT22920
      DO 30 I=K,N                                                       OPT22930
      F=A(J,I)                                                          OPT22940
      A(J,I)=A(M,I)                                                     OPT22950
      A(M,I)=F                                                          OPT22960
30    CONTINUE                                                          OPT22970
40    GO TO (50,90), IEXC                                               OPT22980
C-----SEARCH FOR ROWS ISOLATING AN EIGENVALUE AND PUSH THEM DOWN--------OPT22990
50    IF (L .EQ. 1) GO TO 230                                           OPT23000
      L=L-1                                                             OPT23010
60    DO 80 JJ=1,L                                                      OPT23020
      J=L+1-JJ                                                          OPT23030
      DO 70 I=1,L                                                       OPT23040
      IF (I .EQ. J) GO TO 70                                              OPT23050
      IF (A(J,I) .NE. 0.0D0) GO TO 80                                     OPT23060
   70 CONTINUE                                                            OPT23070
      M=L                                                                 OPT23080
      IEXC=1                                                              OPT23090
      GO TO 10                                                            OPT23100
   80 CONTINUE                                                            OPT23110
      GO TO 100                                                           OPT23120
C-------SEARCH FOR COLUMNS ISOLATING AN EIGENVALUE AND PUSH THEM LEFT---OPT23130
   90 K=K+1                                                               OPT23140
  100 DO 120 J=K,L                                                        OPT23150
      DO 110 I=K,L                                                        OPT23160
      IF (I .EQ. J) GO TO 110                                             OPT23170
      IF (A(I,J) .NE. 0.0D0) GO TO 120                                    OPT23180
  110 CONTINUE                                                            OPT23190
      M=K                                                                 OPT23200
      IEXC=2                                                              OPT23210
      GO TO 10                                                            OPT23220
  120 CONTINUE                                                            OPT23230
C---------------NOW BALANCE THE SUBMATRIX IN ROWS K TO L--------------OPT23240
      DO 130 I=K,L                                                        OPT23250
  130 SCALE(I)=1.0D0                                                      OPT23260
C---------------ITERATIVE LOOP FOR NORM REDUCTION----------------------OPT23270
  140 NOCONV=.FALSE.                                                      OPT23280
      DO 220 I=K,L                                                        OPT23290
      C=0.0D0                                                             OPT23300
      R=0.0D0                                                             OPT23310
      DO 150 J=K,L                                                        OPT23320
      IF (J .EQ. I) GO TO 150                                             OPT23330
      C=C+DABS(A(J,I))                                                    OPT23340
      R=R+DABS(A(I,J))                                                    OPT23350
  150 CONTINUE                                                            OPT23360
C---------------GUARD AGAINST ZERO C OR R DUE TO UNDERFLOW-------------OPT23370
      IF (C .EQ. 0.0D0 .OR. R .EQ. 0.0D0) GO TO 220                       OPT23380
      G=R/RADIX                                                           OPT23390
      F=1.0D0                                                             OPT23400
      S=C+R                                                               OPT23410
  160 IF (C .GE. G) GO TO 170                                             OPT23420
      F=F*RADIX                                                           OPT23430
      C=C*B2                                                              OPT23440
      GO TO 160                                                           OPT23450
  170 G=R*RADIX                                                           OPT23460
  180 IF (C .LT. G) GO TO 190                                             OPT23470
      F=F/RADIX                                                           OPT23480
      C=C/B2                                                              OPT23490
      GO TO 180                                                           OPT23500
C------------------------------NOW BALANCE-----------------------------OPT23510
  190 IF ((C + R) / F .GE. 0.95D0 * S) GO TO 220                          OPT23520
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      G=1.0D0/F                                                         OPT23530
      SCALE(I)=SCALE(I)*F                                               OPT23540
      NOCONV=.TRUE.                                                     OPT23550
      DO 200 J=K,N                                                      OPT23560
  200 A(I,J)=A(I,J)*G                                                   OPT23570
      DO 210 J=1,L                                                      OPT23580
  210 A(J,I)=A(J,I)*F                                                   OPT23590
  220 CONTINUE                                                          OPT23600
      IF (NOCONV) GO TO 140                                             OPT23610
  230 LOW=K                                                             OPT23620
      IGH=L                                                             OPT23630
      RETURN                                                            OPT23640
      END                                                               OPT23650
C=======================================================================OPT23660
      SUBROUTINE CRTHES (NM,N,LOW,IGH,A,ORT)                            OPT23670
      INTEGER I,J,M,N,II,JJ,LA,MP,NM,IGH,KP1,LOW                        OPT23680
      REAL*8 A(NM,N),ORT(IGH)                                           OPT23690
      REAL*8 F,G,H,SCALE                                                OPT23700
      REAL*8 DSQRT,DABS,DSIGN                                           OPT23710
      LA=IGH-1                                                          OPT23720
      KP1=LOW+1                                                         OPT23730
      IF (LA .LT. KP1) GO TO 100                                        OPT23740
      DO 90 M=KP1,LA                                                    OPT23750
      H=0.0D0                                                           OPT23760
      ORT(M)=0.0D0                                                      OPT23770
      SCALE=0.0D0                                                       OPT23780
C--------------SCALE COLUMN (ALGOL TOL THEN NOT NEEDED)-----------------OPT23790
      DO 10 I=M,IGH                                                     OPT23800
   10 SCALE=SCALE+DABS(A(I,M-1))                                        OPT23810
      IF (SCALE .EQ. 0.0D0) GO TO 90                                    OPT23820
      MP=M+IGH                                                          OPT23830
      DO 20 II=M,IGH                                                    OPT23840
      I=MP-II                                                           OPT23850
      ORT(I)=A(I,M-1)/SCALE                                             OPT23860
      H=H+ORT(I)*ORT(I)                                                 OPT23870
   20 CONTINUE                                                          OPT23880
      G=-DSIGN(DSQRT(H),ORT(M))                                         OPT23890
      H=H-ORT(M)*G                                                      OPT23900
      ORT(M)=ORT(M)-G                                                   OPT23910
C----------------------FORM (I-(U*UT)/H) * A---------------------------OPT23920
      DO 50 J=M,N                                                       OPT23930
      F=0.0D0                                                           OPT23940
      DO 30 II=M,IGH                                                    OPT23950
      I=MP-II                                                           OPT23960
      F=F+ORT(I)*A(I,J)                                                 OPT23970
   30 CONTINUE                                                          OPT23980
      F=F/H                                                             OPT23990
      DO 40 I=M,IGH                                                     OPT24000
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40    A(I,J)=A(I,J)-F*ORT(I)                                            OPT24010
50    CONTINUE                                                          OPT24020
C----------------FORM (I-(U*UT)/H)*A*(I-(U*UT)/H)-----------------------OPT24030
      DO 80 I=1,IGH                                                     OPT24040
      F=0.0D0                                                           OPT24050
      DO 60 JJ=M,IGH                                                    OPT24060
      J=MP-JJ                                                           OPT24070
      F=F+ORT(J)*A(I,J)                                                 OPT24080
60    CONTINUE                                                          OPT24090
      F=F/H                                                             OPT24100
      DO 70 J=M,IGH                                                     OPT24110
70    A(I,J)=A(I,J)-F*ORT(J)                                            OPT24120
80    CONTINUE                                                          OPT24130
      ORT(M)=SCALE*ORT(M)                                               OPT24140
      A(M,M-1)=SCALE*G                                                  OPT24150
90    CONTINUE                                                          OPT24160
100   RETURN                                                            OPT24170
      END                                                               OPT24180
C=======================================================================OPT24190
      SUBROUTINE ORTRAN (NM,N,LOW,IGH,A,ORT,Z)                          OPT24200
      INTEGER I,J,N,KL,MM,MP,NM,IGH,LOW,MP1                             OPT24210
      REAL*8 A(NM,IGH),ORT(IGH),Z(NM,N)                                 OPT24220
      REAL*8 G                                                          OPT24230
C----------------INITIALIZE Z TO IDENTITY MATRIX------------------------OPT24240
      DO 20 I=1,N                                                       OPT24250
      DO 10 J=1,N                                                       OPT24260
10    Z(I,J)=0.0D0                                                      OPT24270
      Z(I,I)=1.0D0                                                      OPT24280
20    CONTINUE                                                          OPT24290
      KL=IGH-LOW-1                                                      OPT24300
      IF (KL .LT. 1) GO TO 80                                           OPT24310
      DO 70 MM=1,KL                                                     OPT24320
      MP=IGH-MM                                                         OPT24330
      IF (A(MP,MP-1) .EQ. 0.0D0) GO TO 70                               OPT24340
      MP1=MP+1                                                          OPT24350
      DO 30 I=MP1,IGH                                                   OPT24360
30    ORT(I)=A(I,MP-1)                                                  OPT24370
      DO 60 J=MP,IGH                                                    OPT24380
      G=0.0D0                                                           OPT24390
      DO 40 I=MP,IGH                                                    OPT24400
40    G=G+ORT(I)*Z(I,J)                                                 OPT24410
C----------------DIVISOR BELOW IS NEGATIVE OF H FORMED IN ORTHES.-------OPT24420
C----------------DOUBLE DIVISION AVOIDS POSSIBLE UNDERFLOW--------------OPT24430
      G=(G / ORT(MP))/A(MP,MP-1)                                        OPT24440
      DO 50 I=MP,IGH                                                    OPT24450
50    Z(I,J)=Z(I,J)+G*ORT(I)                                            OPT24460
60    CONTINUE                                                          OPT24470
70    CONTINUE                                                          OPT24480
```

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80    RETURN                                                            OPT24490
      END                                                               OPT24500
C=======================================================================OPT24510
      SUBROUTINE HQR2 (NM,N,LOW,IGH,H,WR,WI,Z,IERR)                     OPT24520
      INTEGER I,J,K,L,M,N,EN,II,JJ,LL,MM,NA,NM,NN,IGH,ITS,LOW,MP2,ENM2,IOPT24530
     1ERR                                                               OPT24540
      REAL*8 H(NM,N),WR(N),WI(N),Z(NM,N)                                OPT24550
      REAL*8 P,Q,R,S,T,W,X,Y,RA,SA,VI,VR,ZZ,NORM,MACHEP                 OPT24560
      REAL*8 DSQRT,DABS,DSIGN                                           OPT24570
      INTEGER MIN0                                                      OPT24580
      LOGICAL NOTLAS                                                    OPT24590
      COMPLEX *16Z3                                                     OPT24600
      COMPLEX *16DCMPLX                                                 OPT24610
      REAL*8 DREAL,DIMAG                                                OPT24620
C----------STATEMENT FUNCTIONS ENABLE EXTRACTION OF REAL AND IMAGINARY--OPT24630
C----------PARTS OF DOUBLE PRECISION COMPLEX NUMBERS--------------------OPT24640
      DREAL(Z3)=Z3                                                      OPT24650
      DIMAG(Z3)=(0.0D0,-1.0D0)*Z3                                       OPT24660
      DATA MACHEP/Z3410000000000000/                                    OPT24670
      IERR=0                                                            OPT24680
      NORM=0.0D0                                                        OPT24690
      K=1                                                               OPT24700
C-------STORE ROOTS ISOLATED BY BALANC AND COMPUTE MATRIX NORM----------OPT24710
      DO 20 I=1,N                                                       OPT24720
      DO 10 J=K,N                                                       OPT24730
10    NORM=NORM+DABS(H(I,J))                                            OPT24740
      K=I                                                               OPT24750
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 20                         OPT24760
      WR(I)=H(I,I)                                                      OPT24770
      WI(I)=0.0D0                                                       OPT24780
20    CONTINUE                                                          OPT24790
      EN=IGH                                                            OPT24800
      T=0.0D0                                                           OPT24810
C---------------SEARCH FOR NEXT EIGENVALUES-----------------------------OPT24820
30    IF (EN .LT. LOW) GO TO 290                                        OPT24830
      ITS=0                                                             OPT24840
      NA=EN-1                                                           OPT24850
      ENM2=NA-1                                                         OPT24860
C---------------LOOK FOR SINGLE SMALL SUB-DIAGONAL ELEMENT--------------OPT24870
40    DO 50 LL=LOW,EN                                                   OPT24880
      L=EN+LOW-LL                                                       OPT24890
      IF (L .EQ. LOW) GO TO 60                                          OPT24900
      S=DABS(H(L-1,L-1))+DABS(H(L,L))                                   OPT24910
      IF (S .EQ. 0.0D0) S=NORM                                          OPT24920
      IF (DABS(H(L,L-1)) .LE. MACHEP * S) GO TO 60                      OPT24930
50    CONTINUE                                                          OPT24940
C-----------------------------FORM SHIFT--------------------------------OPT24950
60    X=H(EN,EN)                                                        OPT24960
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```
      IF (L .EQ. EN) GO TO 220                                          OPT24970
      Y=H(NA,NA)                                                        OPT24980
      W=H(EN,NA)*H(NA,EN)                                               OPT24990
      IF (L .EQ. NA) GO TO 230                                          OPT25000
      IF (ITS .EQ. 30) GO TO 500                                        OPT25010
      IF (ITS .NE. 10 .AND. ITS .NE. 20) GO TO 80                       OPT25020
C-------------------FORM EXCEPTIONAL SHIFT------------------------------OPT25030
      T=T+X                                                             OPT25040
      DO 70 I=LOW,EN                                                    OPT25050
70    H(I,I)=H(I,I)-X                                                   OPT25060
      S=DABS(H(EN,NA))+DABS(H(NA,ENM2))                                 OPT25070
      X=0.75D0*S                                                        OPT25080
      Y=X                                                               OPT25090
      W=-0.4375D0*S*S                                                   OPT25100
80    ITS=ITS+1                                                         OPT25110
C---------LOOK FOR TWO CONSECUTIVE SMALL SUB-DIAGONAL ELEMENTS.---------OPT25120
      DO 90 MM=L,ENM2                                                   OPT25130
      M=ENM2+L-MM                                                       OPT25140
      ZZ=H(M,M)                                                         OPT25150
      R=X-ZZ                                                            OPT25160
      S=Y-ZZ                                                            OPT25170
      P=(R * S - W)/H(M+1,M)+H(M,M+1)                                   OPT25180
      Q=H(M+1,M+1)-ZZ-R-S                                               OPT25190
      R=H(M+2,M+1)                                                      OPT25200
      S=DABS(P)+DABS(Q)+DABS(R)                                         OPT25210
      P=P/S                                                             OPT25220
      Q=Q/S                                                             OPT25230
      R=R/S                                                             OPT25240
      IF (M .EQ. L) GO TO 100                                           OPT25250
      IF (DABS(H(M,M-1)) * (DABS(Q) + DABS(R)) .LE. MACHEP * DABS(P)    OPT25260
     1 * (DABS(H(M-1,M-1)) + DABS(ZZ) + DABS(H(M+1,M+1)))) GO TO 100    OPT25270
90    CONTINUE                                                          OPT25280
100   MP2=M+2                                                           OPT25290
      DO 110 I=MP2,EN                                                   OPT25300
      H(I,I-2)=0.0D0                                                    OPT25310
      IF (I .EQ. MP2) GO TO 110                                         OPT25320
      H(I,I-3)=0.0D0                                                    OPT25330
110   CONTINUE                                                          OPT25340
C--------DOUBLE QR STEP INVOLVING ROWS L TO EN AND COLUMNS M TO EN------OPT25350
      DO 210 K=M,NA                                                     OPT25360
      NOTLAS=K.NE.NA                                                    OPT25370
      IF (K .EQ. M) GO TO 120                                           OPT25380
      P=H(K,K-1)                                                        OPT25390
      Q=H(K+1,K-1)                                                      OPT25400
      R=0.0D0                                                           OPT25410
      IF (NOTLAS) R=H(K+2,K-1)                                          OPT25420
      X=DABS(P)+DABS(Q)+DABS(R)                                         OPT25430
      IF (X .EQ. 0.0D0) GO TO 210                                       OPT25440
      P=P/X                                                             OPT25450
      C=Q/X                                                             OPT25460
      R=R/X                                                             OPT25470
120   S=DSIGN(DSCRT(P*P+Q*C+R*R),P)                                     OPT25480
      IF (K .EC. M) GC TC 130                                           OPT25490
      H(K,K-1)=-S*X                                                     OPT25500
      GC TO 140                                                         OPT25510
130   IF (L .NE. M) H(K,K-1)=-H(K,K-1)                                  OPT25520
140   P=P+S                                                             OPT25530
      X=P/S                                                             OPT25540
      Y=Q/S                                                             OPT25550
      ZZ=R/S                                                            OPT25560
      Q=Q/P                                                             OPT25570
      R=R/P                                                             OPT25580
C-------------------------ROW MODIFICATION---------------------------OPT25590
      DO 160 J=K,N                                                      OPT25600
      P=H(K,J)+Q*H(K+1,J)                                               OPT25610
      IF (.NOT. NCTLAS) GO TC 150                                       OPT25620
      P=P+R*H(K+2,J)                                                    OPT25630
      H(K+2,J)=H(K+2,J)-P*ZZ                                            OPT25640
150   H(K+1,J)=H(K+1,J)-P*Y                                             OPT25650
      H(K,J)=H(K,J)-P*X                                                 OPT25660
160   CCNTINUE                                                          OPT25670
      J=MINO(EN,K+3)                                                    OPT25680
C-----------------------COLUMN MODIFICATION--------------------------OPT25690
      DC 180 I=1,J                                                      OPT25700
      P=X*H(I,K)+Y*H(I,K+1)                                             OPT25710
      IF (.NOT. NCTLAS) GO TO 170                                       OPT25720
      P=P+ZZ*H(I,K+2)                                                   OPT25730
      H(I,K+2)=H(I,K+2)-P*R                                             OPT25740
170   H(I,K+1)=H(I,K+1)-P*C                                             OPT25750
      H(I,K)=H(I,K)-P                                                   OPT25760
180   CCNTINUE                                                          OPT25770
C---------------------ACCUMULATE TRANSFORMATICNS---------------------OPT25780
      DO 200 I=LCW,IGH                                                  OPT25790
      P=X*Z(I,K)+Y*Z(I,K+1)                                             OPT25800
      IF (.NOT. NCTLAS) GC TO 190                                       OPT25810
      P=P+ZZ*Z(I,K+2)                                                   OPT25820
      Z(I,K+2)=Z(I,K+2)-P*R                                             OPT25830
190   Z(I,K+1)=Z(I,K+1)-P*C                                             OPT25840
      Z(I,K)=Z(I,K)-P                                                   OPT25850
200   CONTINUE                                                          OPT25860
210   CCNTINUE                                                          OPT25870
      GO TO 40                                                          OPT25880
C----------------------------ONE ROOT FOUND--------------------------OPT25890
220   H(EN,EN)=X+T                                                      OPT25900
      WR(EN)=H(EN,EN)                                                   OPT25910
      WI(EN)=0.0DC                                                      OPT25920
      EN=NA                                                             OPT25930
      GO TO 30                                                          OPT25940
C-------------------------TWO ROOTS FOUND-------------------------------OPT25950
230   P=(Y - X)/2.0D0                                                   OPT25960
      C=P*P+W                                                           OPT25970
      ZZ=DSQRT(DABS(Q))                                                 OPT25980
      H(EN,EN)=X+T                                                      OPT25990
      X=H(EN,EN)                                                        OPT26000
      H(NA,NA)=Y+T                                                      OPT26010
      IF (Q .LT. C.0D0) GO TO 270                                       OPT26020
C-------------------------REAL PAIR-------------------------------------OPT26030
      ZZ=P+DSIGN(ZZ,P)                                                  OPT26040
      WR(NA)=X+ZZ                                                       OPT26050
      WR(EN)=WR(NA)                                                     OPT26060
      IF (ZZ .NE. C.0D0) WR(EN)=X-W/ZZ                                  OPT26070
      WI(NA)=0.0D0                                                      OPT26080
      WI(EN)=0.0D0                                                      OPT26090
      X=H(EN,NA)                                                        OPT26100
      S=DABS(X)+DABS(ZZ)                                                OPT26110
      P=X/S                                                             OPT26120
      Q=ZZ/S                                                            OPT26130
      R=DSQRT(P*P+Q*Q)                                                  OPT26140
      P=P/R                                                             OPT26150
      C=Q/R                                                             OPT26160
C-------------------------ROW MODIFICATION------------------------------OPT26170
      DO 240 J=NA,N                                                     OPT26180
      ZZ=H(NA,J)                                                        OPT26190
      H(NA,J)=Q*ZZ+P*H(EN,J)                                            OPT26200
      H(EN,J)=Q*H(EN,J)-P*ZZ                                            OPT26210
240   CONTINUE                                                          OPT26220
C-------------------------COLUMN MODIFICATION---------------------------OPT26230
      DO 250 I=1,EN                                                     OPT26240
      ZZ=H(I,NA)                                                        OPT26250
      H(I,NA)=Q*ZZ+P*H(I,EN)                                            OPT26260
      H(I,EN)=Q*H(I,EN)-P*ZZ                                            OPT26270
250   CONTINUE                                                          OPT26280
C-------------------------ACCUMULATE TRANSFORMATIONS--------------------OPT26290
      DO 260 I=LOW,IGH                                                  OPT26300
      ZZ=Z(I,NA)                                                        OPT26310
      Z(I,NA)=Q*ZZ+P*Z(I,EN)                                            OPT26320
      Z(I,EN)=Q*Z(I,EN)-P*ZZ                                            OPT26330
260   CONTINUE                                                          OPT26340
      GO TO 280                                                         OPT26350
C-------------------------COMPLEX PAIR----------------------------------OPT26360
270   WR(NA)=X+P                                                        OPT26370
      WR(EN)=X+P                                                        OPT26380
      WI(NA)=ZZ                                                         OPT26390
      WI(EN)=-ZZ                                                        OPT26400
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280   EN=ENM2                                                           OPT26410
      GO TO 30                                                          OPT26420
C---------------ALL ROOTS FOUND.  BACKSUBSTITUTE TO FIND---------------OPT26430
C---------------VECTORS OF UPPER TRIANGULAR FORM------------------------OPT26440
290   IF (NORM .EQ. 0.0D0) GO TO 510                                    OPT26450
      DO 450 NN=1,N                                                     OPT26460
      EN=N+1-NN                                                         OPT26470
      P=WR(EN)                                                          OPT26480
      Q=WI(EN)                                                          OPT26490
      NA=EN-1                                                           OPT26500
      IF (Q) 370,300,450                                                OPT26510
C---------------------------REAL VECTOR---------------------------------OPT26520
300   M=EN                                                              OPT26530
      H(EN,EN)=1.0D0                                                    OPT26540
      IF (NA .EQ. 0) GO TO 450                                          OPT26550
      DO 360 II=1,NA                                                    OPT26560
      I=EN-II                                                           OPT26570
      W=H(I,I)-P                                                        OPT26580
      R=H(I,EN)                                                         OPT26590
      IF (M .GT. NA) GO TO 320                                          OPT26600
      DO 310 J=M,NA                                                     OPT26610
310   R=R+H(I,J)*H(J,EN)                                                OPT26620
320   IF (WI(I) .GE. 0.0D0) GO TO 330                                   OPT26630
      ZZ=W                                                              OPT26640
      S=R                                                               OPT26650
      GO TO 360                                                         OPT26660
330   M=I                                                               OPT26670
      IF (WI(I) .NE. 0.0D0) GO TO 340                                   OPT26680
      T=W                                                               OPT26690
      IF (W .EQ. 0.0D0) T=MACHEP*NORM                                   OPT26700
      H(I,EN)=-R/T                                                      OPT26710
      GO TO 360                                                         OPT26720
C--------------------------SOLVE REAL EQUATIONS-------------------------OPT26730
340   X=H(I,I+1)                                                        OPT26740
      Y=H(I+1,I)                                                        OPT26750
      Q=(WR(I) - P)*(WR(I) - P)+WI(I)*WI(I)                             OPT26760
      T=(X * S - ZZ * R)/Q                                              OPT26770
      H(I,EN)=T                                                         OPT26780
      IF (DABS(X) .LE. DABS(ZZ)) GO TO 350                              OPT26790
      H(I+1,EN)=(-R - W * T)/X                                          OPT26800
      GO TO 360                                                         OPT26810
350   H(I+1,EN)=(-S - Y * T)/ZZ                                         OPT26820
360   CONTINUE                                                          OPT26830
C--------------------------END REAL VECTOR------------------------------OPT26840
      GO TO 450                                                         OPT26850
C--------------------------COMPLEX VECTOR-------------------------------OPT26860
370   M=NA                                                              OPT26870
C---------------LAST VECTOR COMPONENT CHOSEN IMAGINARY SO THAT----------OPT26880
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C----------------EIGENVECTOR MATRIX IS TRIANGULAR----------------------OPT26890
      IF (DABS(H(EN,NA)) .LE. DABS(H(NA,EN))) GO TO 380                 OPT26900
      H(NA,NA)=Q/H(EN,NA)                                               OPT26910
      H(NA,EN)=-(H(EN,EN) - P)/H(EN,NA)                                 OPT26920
      GO TO 390                                                         OPT26930
  380 Z3=DCMPLX(0.0D0,-H(NA,EN))/DCMPLX(H(NA,NA)-P,Q)                   OPT26940
      H(NA,NA)=DREAL(Z3)                                                OPT26950
      H(NA,EN)=DIMAG(Z3)                                                OPT26960
  390 H(EN,NA)=0.0D0                                                    OPT26970
      H(EN,EN)=1.0D0                                                    OPT26980
      ENM2=NA-1                                                         OPT26990
      IF (ENM2 .EQ. 0) GO TO 450                                        OPT27000
      DO 440 II=1,ENM2                                                  OPT27010
      I=NA-II                                                           OPT27020
      W=H(I,I)-P                                                        OPT27030
      RA=0.0D0                                                          OPT27040
      SA=H(I,EN)                                                        OPT27050
      DO 400 J=M,NA                                                     OPT27060
      RA=RA+H(I,J)*H(J,NA)                                              OPT27070
      SA=SA+H(I,J)*H(J,EN)                                              OPT27080
  400 CONTINUE                                                          OPT27090
      IF (WI(I) .GE. 0.0D0) GO TO 410                                   OPT27100
      ZZ=W                                                              OPT27110
      R=RA                                                              OPT27120
      S=SA                                                              OPT27130
      GO TO 440                                                         OPT27140
  410 M=I                                                               OPT27150
      IF (WI(I) .NE. 0.0D0) GO TO 420                                   OPT27160
      Z3=DCMPLX(-RA,-SA)/DCMPLX(W,Q)                                    OPT27170
      H(I,NA)=DREAL(Z3)                                                 OPT27180
      H(I,EN)=DIMAG(Z3)                                                 OPT27190
      GO TO 440                                                         OPT27200
C-------------------------SOLVE COMPLEX EQUATIONS-----------------------OPT27210
  420 X=H(I,I+1)                                                        OPT27220
      Y=H(I+1,I)                                                        OPT27230
      VR=(WR(I) - P)*(WR(I) - P)+WI(I)*WI(I)-Q*Q                        OPT27240
      VI=(WR(I) - P)*2.0D0*Q                                            OPT27250
      IF (VR .EQ. 0.0D0 .AND. VI .EQ. 0.0D0) VR=MACHEP*NORM*(DABS(W) + DOPT27260
     1ABS(Q) + DABS(X) + DABS(Y) + DABS(ZZ))                            OPT27270
      Z3=DCMPLX(X*R-ZZ*RA+Q*SA,X*S-ZZ*SA-Q*RA)/DCMPLX(VR,VI)            OPT27280
      H(I,NA)=DREAL(Z3)                                                 OPT27290
      H(I,EN)=DIMAG(Z3)                                                 OPT27300
      IF (DABS(X) .LE. DABS(ZZ) + DABS(Q)) GO TO 430                    OPT27310
      H(I+1,NA)=(-RA - W * H(I,NA) + Q * H(I,EN))/X                     OPT27320
      H(I+1,EN)=(-SA - W * H(I,EN) - Q * H(I,NA))/X                     OPT27330
      GO TO 440                                                         OPT27340
  430 Z3=DCMPLX(-R-Y*H(I,NA),-S-Y*H(I,EN))/DCMPLX(ZZ,Q)                 OPT27350
      H(I+1,NA)=DREAL(Z3)                                               OPT27360
      H(I+1,EN)=CIMAG(Z3)                                                OPT27370
440   CONTINUE                                                           OPT27380
C-----------------------------END COMPLEX VECTOR-------------------------OPT27390
450   CONTINUE                                                           OPT27400
C-------------END BACK SUBSTITUTION. VECTORS OF ISOLATED ROOTS-----------OPT27410
      DO 470 I=1,N                                                       OPT27420
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 470                         OPT27430
      DO 460 J=I,N                                                       OPT27440
460   Z(I,J)=H(I,J)                                                      OPT27450
470   CONTINUE                                                           OPT27460
C---------------MULTIPLY BY TRANSFORMATION MATRIX TO GIVE----------------OPT27470
C---------------VECTORS OF ORIGINAL FULL MATRIX.-------------------------OPT27480
      DO 490 JJ=LOW,N                                                    OPT27490
      J=N+LOW-JJ                                                         OPT27500
      M=MIN0(J,IGH)                                                      OPT27510
      DO 490 I=LOW,IGH                                                   OPT27520
      ZZ=0.0D0                                                           OPT27530
      DO 480 K=LOW,M                                                     OPT27540
480   ZZ=ZZ+Z(I,K)*H(K,J)                                                OPT27550
      Z(I,J)=ZZ                                                          OPT27560
490   CONTINUE                                                           OPT27570
      GO TO 510                                                          OPT27580
C---------------SET ERROR -->NO CONVERGENCE TO AN------------------------OPT27590
C---------------EIGENVALUE AFTER 30 ITERATIONS---------------------------OPT27600
500   IERR=EN                                                            OPT27610
510   RETURN                                                             OPT27620
      END                                                                OPT27630
C=======================================================================OPT27640
      SUBROUTINE BALBAK (NM,N,LOW,IGH,SCALE,M,Z)                         OPT27650
      INTEGER I,J,K,M,N,II,NM,IGH,LOW                                    OPT27660
      REAL*8 SCALE(N),Z(NM,M),S                                          OPT27670
      IF (M .EQ. 0) GO TO 60                                             OPT27680
      IF (IGH .EQ. LOW) GO TO 30                                         OPT27690
      DO 20 I=LOW,IGH                                                    OPT27700
      S=SCALE(I)                                                         OPT27710
C---------------LEFT HAND EIGENVECTORS ARE BACK TRANSFORMED--------------OPT27720
C---------------IF THE FOREGOING STATEMENT IS REPLACED BY----------------OPT27730
C---------------S=1.0D0/SCALE(I).----------------------------------------OPT27740
      DO 10 J=1,M                                                        OPT27750
10    Z(I,J)=Z(I,J)*S                                                    OPT27760
20    CONTINUE                                                           OPT27770
30    DO 50 II=1,N                                                       OPT27780
      I=II                                                               OPT27790
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 50                          OPT27800
      IF (I .LT. LOW) I=LOW-II                                           OPT27810
      K=SCALE(I)                                                         OPT27820
      IF (K .EQ. I) GO TO 50                                             OPT27830
      DO 40 J=1,M                                                        OPT27840
      S=Z(I,J)                                                          OPT27850
      Z(I,J)=Z(K,J)                                                     OPT27860
      Z(K,J)=S                                                          OPT27870
 4C   CCNTINUE                                                          OPT27880
 5C   CCNTINUE                                                          OPT27890
 6C   RETURN                                                            OPT27900
      END                                                               OPT27910
C=======================================================================OPT27920
      SUBROUTINE HQR (NM,N,LOW,IGH,H,WR,WI,IERR)                        OPT27930
      INTEGER I,J,K,L,M,N,EN,LL,MM,NA,NM,IGH,ITS,LCW,MP2,ENM2,IERR      OPT27940
      REAL*8 H(NM,N),WR(N),WI(N)                                        OPT27950
      REAL*8 P,Q,R,S,T,W,X,Y,ZZ,NORM,MACHEP                             OPT27960
      REAL*8 DSQRT,DABS,DSIGN                                           OPT27970
      INTEGER MINO                                                      OPT27980
      LCGICAL NOTLAS                                                    OPT27990
      DATA MACHEP/Z3410000000000000/                                    OPT28000
      IERR=0                                                            OPT28010
      NORM=0.0D0                                                        OPT28020
      K=1                                                               OPT28030
C--------STORE RCCTS ISOLATED BY BALANC AND COMPUTE MATRIX NORM---------OPT28040
      CO 20 I=1,N                                                       OPT28050
      CO 10 J=K,N                                                       OPT28060
 1C   NORM=NORM+DABS(H(I,J))                                            OPT28070
      K=I                                                               OPT28080
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 20                         OPT28090
      WR(I)=H(I,I)                                                      OPT28100
      WI(I)=0.0DC                                                       OPT28110
 2C   CONTINUE                                                          OPT28120
      EN=IGH                                                            OPT28130
      T=0.0D0                                                           OPT28140
C----------------------SEARCH FOR NEXT EIGENVALUES-----------------------OPT28150
 3C   IF (EN .LT. LOW) GO TO 250                                        OPT28160
      ITS=0                                                             OPT28170
      NA=EN-1                                                           OPT28180
      ENM2=NA-1                                                         OPT28190
C--------------LOCK FOR SINGLE SMALL SUB-DIAGCNAL ELEMENT---------------OPT28200
 40   CC 50 LL=LCW,EN                                                   OPT28210
      L=EN+LCW-LL                                                       OPT28220
      IF (L .EQ. LOW) GO TC 60                                          OPT28230
      S=DABS(H(L-1,L-1))+DABS(H(L,L))                                   OPT28240
      IF (S .EQ. C.0D0) S=NORM                                          OPT28250
      IF (DABS(H(L,L-1)) .LE. MACHEP * S) GO TO 60                      OPT28260
 50   CCNTINUE                                                          OPT28270
C-------------------------FORM SHIFT------------------------------------OPT28280
 6C   X=H(EN,EN)                                                        OPT28290
      IF (L .EQ. EN) GO TC 200                                          OPT28300
      Y=H(NA,NA)                                                        OPT28310
      W=H(EN,NA)*H(NA,EN)                                               OPT28320
      IF (L .EQ. NA) GO TO 210                                          OPT28330
      IF (ITS .EQ. 30) GO TO 240                                        OPT28340
      IF (ITS .NE. 10 .AND. ITS .NE. 20) GO TO 80                       OPT28350
C-------------------------FORM EXCEPTIONAL SHIFT-------------------------OPT28360
      T=T+X                                                             OPT28370
      DO 70 I=LOW,EN                                                    OPT28380
70    H(I,I)=H(I,I)-X                                                   OPT28390
      S=DABS(H(EN,NA))+DABS(H(NA,ENM2))                                 OPT28400
      X=0.75D0*S                                                        OPT28410
      Y=X                                                               OPT28420
      W=-0.4375D0*S*S                                                   OPT28430
80    ITS=ITS+1                                                         OPT28440
C----------LOOK FOR TWO CONSECUTIVE SMALL SUB-DIAGONAL ELEMENTS.---------OPT28450
      DO 90 MM=L,ENM2                                                   OPT28460
      M=ENM2+L-MM                                                       OPT28470
      ZZ=H(M,M)                                                         OPT28480
      R=X-ZZ                                                            OPT28490
      S=Y-ZZ                                                            OPT28500
      P=(R * S - W)/H(M+1,M)+H(M,M+1)                                   OPT28510
      Q=H(M+1,M+1)-ZZ-R-S                                               OPT28520
      R=H(M+2,M+1)                                                      OPT28530
      S=DABS(P)+DABS(Q)+DABS(R)                                         OPT28540
      P=P/S                                                             OPT28550
      Q=Q/S                                                             OPT28560
      R=R/S                                                             OPT28570
      IF (M .EQ. L) GO TO 100                                           OPT28580
      IF (DABS(H(M,M-1)) * (DABS(Q) + DABS(R)) .LE. MACHEP * DABS(P)    OPT28590
     1 * (DABS(H(M-1,M-1)) + DABS(ZZ) + DABS(H(M+1,M+1)))) GO TO 100    OPT28600
90    CONTINUE                                                          OPT28610
100   MP2=M+2                                                           OPT28620
      DO 110 I=MP2,EN                                                   OPT28630
      H(I,I-2)=0.0D0                                                    OPT28640
      IF (I .EQ. MP2) GO TO 110                                         OPT28650
      H(I,I-3)=0.0D0                                                    OPT28660
110   CONTINUE                                                          OPT28670
C------DOUBLE QR STEP INVOLVING ROWS L TO EN AND COLUMNS M TO EN---------OPT28680
      DO 190 K=M,NA                                                     OPT28690
      NOTLAS=K.NE.NA                                                    OPT28700
      IF (K .EQ. M) GO TO 120                                           OPT28710
      P=H(K,K-1)                                                        OPT28720
      Q=H(K+1,K-1)                                                      OPT28730
      R=0.0D0                                                           OPT28740
      IF (NOTLAS) R=H(K+2,K-1)                                          OPT28750
      X=DABS(P)+DABS(Q)+DABS(R)                                         OPT28760
      IF (X .EQ. 0.0D0) GO TO 190                                       OPT28770
      P=P/X                                                             OPT28780
      Q=Q/X                                                             OPT28790
      R=R/X                                                             OPT28800
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120   S=DSIGN(DSQRT(P*P+Q*Q+R*R),P)                                          OPT28810
      IF (K .EQ. M) GO TO 130                                                OPT28820
      H(K,K-1)=-S*X                                                          OPT28830
      GO TO 140                                                              OPT28840
130   IF (L .NE. M) H(K,K-1)=-H(K,K-1)                                       OPT28850
140   P=P+S                                                                  OPT28860
      X=P/S                                                                  OPT28870
      Y=Q/S                                                                  OPT28880
      ZZ=R/S                                                                 OPT28890
      Q=Q/P                                                                  OPT28900
      R=R/P                                                                  OPT28910
C-----------------------------ROW MODIFICATION---------------------------OPT28920
      DO 160 J=K,EN                                                          OPT28930
      P=H(K,J)+Q*H(K+1,J)                                                    OPT28940
      IF (.NOT. NOTLAS) GO TO 150                                            OPT28950
      P=P+R*H(K+2,J)                                                         OPT28960
      H(K+2,J)=H(K+2,J)-P*ZZ                                                 OPT28970
150   H(K+1,J)=H(K+1,J)-P*Y                                                  OPT28980
      H(K,J)=H(K,J)-P*X                                                      OPT28990
160   CONTINUE                                                               OPT29000
      J=MINO(EN,K+3)                                                         OPT29010
C-----------------------------COLUMN MODIFICATION------------------------OPT29020
      DO 180 I=L,J                                                           OPT29030
      P=X*H(I,K)+Y*H(I,K+1)                                                  OPT29040
      IF (.NOT. NOTLAS) GO TO 170                                            OPT29050
      P=P+ZZ*H(I,K+2)                                                        OPT29060
      H(I,K+2)=H(I,K+2)-P*R                                                  OPT29070
170   H(I,K+1)=H(I,K+1)-P*Q                                                  OPT29080
      H(I,K)=H(I,K)-P                                                        OPT29090
180   CONTINUE                                                               OPT29100
190   CONTINUE                                                               OPT29110
      GO TO 40                                                               OPT29120
C-----------------------------ONE ROOT FOUND-----------------------------OPT29130
200   WR(EN)=X+T                                                             OPT29140
      WI(EN)=0.0D0                                                           OPT29150
      EN=NA                                                                  OPT29160
      GO TO 30                                                               OPT29170
C-----------------------------TWO ROOTS FOUND----------------------------OPT29180
210   P=(Y - X)/2.0D0                                                        OPT29190
      Q=P*P+W                                                                OPT29200
      ZZ=DSQRT(DABS(Q))                                                      OPT29210
      X=X+T                                                                  OPT29220
      IF (Q .LT. 0.0D0) GO TO 220                                            OPT29230
C-----------------------------REAL PAIR----------------------------------OPT29240
      ZZ=P+DSIGN(ZZ,P)                                                       OPT29250
      WR(NA)=X+ZZ                                                            OPT29260
      WR(EN)=WR(NA)                                                          OPT29270
      IF (ZZ .NE. 0.0D0) WR(EN)=X-W/ZZ                                       OPT29280
      WI(NA)=0.0D0                                                      OPT29290
      WI(EN)=0.0D0                                                      OPT29300
      GO TO 230                                                         OPT29310
C-------------------------COMPLEX PAIR---------------------------------OPT29320
220   WR(NA)=X+P                                                        OPT29330
      WR(EN)=X+P                                                        OPT29340
      WI(NA)=ZZ                                                         OPT29350
      WI(EN)=-ZZ                                                        OPT29360
230   EN=ENM2                                                           OPT29370
      GO TO 30                                                          OPT29380
C---------------SET ERROR -- NO CONVERGENCE TO AN----------------------OPT29390
C---------------EIGENVALUE AFTER 30 ITERATIONS-------------------------OPT29400
240   IERR=EN                                                           OPT29410
250   RETURN                                                            OPT29420
      END                                                               OPT29430
C======================================================================OPT29440
      SUBROUTINE PSDCAL (N2,NS,FA,X,NC,GW,GV ,C,NC,HY,HU,H,             OPT29450
     1  FBGE,NG,GAM,ACL,F,WR,WI,D1,D2,JCF,RES,Q,R,BB,CC,IYU,            OPT29460
     2  IPSD,INORM)                                                     OPT29470
C======================================================================OPT29480
C     =   PSDCAL COMPUTES THE PSD OF OUTPUTS OR CONTROLS OF            =OPT29490
C     =    A CONTROLLED SYSTEM                                         =OPT29500
C     =                                                                =OPT29510
C     =      IYU= 1      OUTPUT PSD                                    =OPT29520
C     =         = 2      CONTROL PSD                                   =OPT29530
C     =         = 3      BOTH OUTPUT AND CONTROL PSD                   =OPT29540
C     =                                                                =OPT29550
C     =      IPSD=1      PSD                                           =OPT29560
C     =          =2      PSD AND TF RESIDUES                           =OPT29570
C     =                                                                =OPT29580
C     =                                                                =OPT29590
C     =      INORM=      1,2,... NG  NORMALIZED BY ITH PROCESS NOISE   =OPT29600
C     =                  NG+1,... NG+NO NORMALIZED BY ITH MEAS NOISE   = OPT29610
C======================================================================OPT29620
      DOUBLE PRECISION FA,X,GW,GV,C,HY,H,FBGE,GAM,ACL,F,WR,WI,D1,D2,RES,OPT29630
     1BB,CC,Q,R,PSD,W,DNORM,DN1,EMAX,ELOG,EMOD,DW,ST,CM,RE,AI,HU,DW1     OPT29640
      COMPLEX *16ZD,ZN,ZZ                                               OPT29650
      DIMENSION FA(N2,N2),X(N2,N2),GW(N2,NG),C(NC,NS),HY(NC,N2),H(NC,NS)OPT29660
     1,FBGE(NS,NC),GAM(NS,NG),ACL(NS,NS),F(NS,NS),WR(N2),WI(N2),D1(N2),DOPT29670
     22(N2),RES(N2),Q(NG,NG),R(NC,NC),PSD(30),W(30),BB(N2),CC(N2),GV(N2,OPT29680
     3NO),HU(NC,N2),DW1(4)                                              OPT29690
      INTEGER JCF(N2)                                                   OPT29700
      DATA DW1/1.D0,2.D0,5.D0,10.D0/                                    OPT29710
      IF (IYU .EQ. 0) IYU=1                                             OPT29720
      IF (INORM .EQ. 0) INORM=1                                         OPT29730
      IPT=0                                                             OPT29740
      IF (IPSD .GT. 1) IPT=1                                            OPT29750
      IX=INORM-NG                                                       OPT29760
      IF (IX .GT. 0) WRITE (6,330) IX                                   OPT29770
      IF (IX .LE. 0) WRITE (6,340) INORM                                OPT29780
      NSQ=N2*N2                                                         OPT29790
C---------COMPUTE EIGENSYSTEM OF CONTROLLED SYSTEM; FORM FA-------------OPT29800
      DO 10 I=1,NS                                                      OPT29810
      DO 10 J=1,NS                                                      OPT29820
      FA(I,J)=ACL(I,J)                                                  OPT29830
10    FA(NS+I,J)=0.D0                                                   OPT29840
      DO 30 I=1,NS                                                      OPT29850
      DO 30 J=1,NS                                                      OPT29860
      ST=0.D0                                                           OPT29870
      DO 20 K=1,NC                                                      OPT29880
20    ST=ST+FBGE(I,K)*H(K,J)                                            OPT29890
      FA(I,NS+J)=-ST                                                    OPT29900
30    FA(NS+I,NS+J)=F(I,J)-ST                                           OPT29910
      CALL RAPRNT (N2,N2,N2,9,FA,4,'(9(1X,1PD13.6))')                   OPT29920
C----------------------------DEBUG ABOVE--------------------------------OPT29930
      CALL BALANC (N2,N2,FA,LOW,IHIGH,D1)                               OPT29940
      CALL ORTHES (N2,N2,LOW,IHIGH,FA,D2)                               OPT29950
      CALL ORTRAN (N2,N2,LOW,IHIGH,FA,D2,X)                             OPT29960
      CALL HQR2 (N2,N2,LOW,IHIGH,FA,WR,WI,X,IERR)                       OPT29970
      IF (IERR .NE. 0) GO TO 320                                        OPT29980
      CALL BALBAK (N2,N2,LOW,IHIGH,D1,N2,X)                             OPT29990
      CALL RAPRNT (N2,N2,N2,9,X,4,'(9(1X,1PD13.6))')                    OPT30000
C-----------DEBUG ABOVE;DETERMINE MODAL MATRICES------------------------OPT30010
      IF (IYU .EQ. 1) GO TO 60                                          OPT30020
C---------------------------HSUBU---------------------------------------OPT30030
      DO 50 I=1,NC                                                      OPT30040
      DO 50 J=1,N2                                                      OPT30050
      ST=0.D0                                                           OPT30060
      DO 40 K=1,NS                                                      OPT30070
40    ST=ST-C(I,K)*X(K,J)                                               OPT30080
50    HU(I,J)=ST                                                        OPT30090
      GO TO 90                                                          OPT30100
C---------------------------HSUBY---------------------------------------OPT30110
60    DO 80 I=1,NC                                                      OPT30120
      DO 80 J=1,N2                                                      OPT30130
      ST=0.D0                                                           OPT30140
      DO 70 K=1,NS                                                      OPT30150
70    ST=ST+H(I,K)*X(K,J)-H(I,K)*X(NS+K,J)                              OPT30160
80    HY(I,J)=ST                                                        OPT30170
      CALL RAPRNT (NO,NC,N2,9,HY,4,'(9(1X,1PD13.6))')                   OPT30180
C---------------------------DEBUG ABOVE---------------------------------OPT30190
90    CALL MINV (NSQ,X,N2,ST,D1,D2)                                     OPT30200
      CALL RAPRNT (N2,N2,N2,9,X,4,'(9(1X,1PD13.6))')                    OPT30210
C---------------------------DEBUG ABOVE---------------------------------OPT30220
C---------------------------GSUBW---------------------------------------OPT30230
      DO 110 I=1,N2                                                     OPT30240
      DO 110 J=1,NG                                                            OPT30250
      ST=0.0D0                                                                 OPT30260
      DO 100 K=1,NS                                                            OPT30270
100   ST=ST-X(I,NS+K)*GAM(K,J)                                                 OPT30280
110   GW(I,J)=ST                                                               OPT30290
      CALL RAPRNT (N2,N2,NG,9,GW,4,'(9(1X,1PD13.6))')                          OPT30300
C-----------DEBUG ABOVE; USE SELECTED NORMALIZATION--------------------------OPT30310
      IF (INORM .LE. NG) DNORM=1.D0/Q(INORM,INORM)                             OPT30320
      IF (INORM .GT. NG) DNORM=1.D0/R(INORM-NG,INORM-NG)                       OPT30330
C-----------------DETERMINE BANDWIDTH OF CONTROLLED SYSTEM-----------------OPT30340
      EMAX=0.D0                                                                OPT30350
      DO 120 I=1,N2                                                            OPT30360
      EMOD=DABS(WR(I)**2 +WI(I)**2)                                            OPT30370
      IF (EMOD .GT. EMAX) EMAX=EMOD                                            OPT30380
120   CONTINUE                                                                 OPT30390
      EMOD=DSQRT(EMAX)                                                         OPT30400
      EMOD=2*EMOD                                                              OPT30410
C-------------------------ROUND UP TO NEAREST 2,4,5,8,10--------------------OPT30420
      ELOG=DLOG10(EMOD)                                                        OPT30430
      IF (ELOG .LT. 0.D0) IPOW=-IDINT(DABS(ELOG) + 1)                          OPT30440
      IF (ELOG .GE. 0.D0) IPOW=IDINT(ELOG)                                     OPT30450
      EMAX=EMOD*10**(-IPOW)                                                    OPT30460
      IF (EMAX .GT. 2.D0) EMOD=2.D0                                            OPT30470
      IF (EMAX .GT. 4.D0) EMOD=4.D0                                            OPT30480
      IF (EMAX .GT. 5.D0) EMOD=5.D0                                            OPT30490
      IF (EMAX .GT. 8.D0) EMOD=8.D0                                            OPT30500
      IF (EMAX .GE. 10.D0) EMOD=10.D0                                          OPT30510
      EMAX=EMOD*10**IPOW                                                       OPT30520
      DW=EMAX/20.D0                                                            OPT30530
C--------------------------ADD 10 POINTS 3 DECADES UP-----------------------OPT30540
      IF (EMOD .LT. 5.0) GO TO 130                                             OPT30550
      EMAX=1.0D1                                                               OPT30560
      IK=3                                                                     OPT30570
      GO TO 140                                                                OPT30580
130   EMAX=5.D0                                                                OPT30590
      IK=2                                                                     OPT30600
140   CONTINUE                                                                 OPT30610
C--------------------------STORE 30 FREQUENCIES-----------------------------OPT30620
      DO 150 I=1,20                                                            OPT30630
150   W(I)=DW*(I-1)                                                            OPT30640
      DO 160 I=1,3                                                             OPT30650
      IP=20+3*(I-1)                                                            OPT30660
      DO 160 J=1,3                                                             OPT30670
      IX=MOD(IK+J-1,3)+1                                                       OPT30680
      JJ=0                                                                     OPT30690
      IF (IK .EQ. 2 .AND. J .GE. 2) JJ=1                                       OPT30700
      W(IP+J)=DWI(IX)*10**(IPOW+I-1+JJ+IK-2)                                   OPT30710
160   CONTINUE                                                                 OPT30720
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      IX=MOD(IK,2)+1                                                    OPT30730
      W(30)=DW1(IX)*10**(IPOW+3 +IK-2)                                  OPT30740
C---------------------LARGE LOOP THRU OUTPUTS---------------------------OPT30750
      IF (IYU .EQ. 1) NL=NC                                             OPT30760
      IF (IYU .EQ. 2) NL=NC                                             OPT30770
      DO 310 L=1,NL                                                     OPT30780
      DO 170 I=1,30                                                     OPT30790
170   PSD(I)=0.D0                                                       OPT30800
C---------------------LOOP THRU PROCESS NOISE---------------------------OPT30810
      DO 220 I=1,NG                                                     OPT30820
      DN1=DNORM*Q(I,I)                                                  OPT30830
      IF (IYU .EQ. 1 .AND. IPT .EQ. 1) WRITE (6,350) I,L                OPT30840
      IF (IYU .EQ. 2 .AND. IPT .EQ. 1) WRITE (6,360) I,L                OPT30850
      IF (IYU.EQ.1) CALL RESID (I,L,N2,JCF,NG,GW,NL,HY,WR,WI,           OPT30860
     1RES,BB,CC,IFT)                                                    OPT30870
      IF (IYU.EQ.2) CALL RESID (I,L,N2,JCF,NG,GW,NL,HU,WR,WI,           OPT30880
     1RES,BB,CC,IFT)                                                    OPT30890
      DO 210 K=1,20                                                     OPT30900
      ZZ=DCMPLX(0.D0,0.D0)                                              OPT30910
      OM=W(K)                                                           OPT30920
      DO 200 II=1,N2                                                    OPT30930
      IF (WI(II)) 200,180,190                                           OPT30940
180   ZD=DCMPLX(-WR(II),OM-WI(II))                                      OPT30950
      ZZ=RES(II)/ZD+ZZ                                                  OPT30960
      GO TO 200                                                         OPT30970
190   RE=WR(II)                                                         OPT30980
      AI=WI(II)                                                         OPT30990
      ZD=DCMPLX(RE**2 + AI**2 - OM**2,-2.D0*RE*OM)                      OPT31000
      ZN=DCMPLX(RES(II+1)*AI-RES(II)*RE,RES(II)*OM)                     OPT31010
      ZZ=ZZ+ZN/ZD                                                       OPT31020
200   CONTINUE                                                          OPT31030
210   PSD(K)=PSD(K)+DN1*(ZZ*DCONJG(ZZ))                                 OPT31040
220   CONTINUE                                                          OPT31050
C-----------------------------GSUBV-------------------------------------OPT31060
      DO 240 I=1,N2                                                     OPT31070
      DO 240 J=1,NC                                                     OPT31080
      ST=0.D0                                                           OPT31090
      DO 230 K=1,NS                                                     OPT31100
230   ST=ST+X(I,K)*FBGE(K,J)+X(I,NS+K)*FBGE(K,J)                        OPT31110
240   GV(I,J)=ST                                                        OPT31120
      CALL RAPRNT (N2,N2,NC,9,GV,4,'(9(1X,1PD13.6))')                   OPT31130
C-----------------DEBUG ABOVE, LOOP THRU MEAS NOISE---------------------OPT31140
      DO 300 I=1,NC                                                     OPT31150
      DN1=DNORM*R(I,I)                                                  OPT31160
      IF (IYU .EQ. 1 .AND. IPT .EQ. 1) WRITE (6,370) I,L                OPT31170
      IF (IYU .EQ. 2 .AND. IPT .EQ. 1) WRITE (6,380) I,L                OPT31180
      IF (IYU.EQ.1) CALL RESID (I,L,N2,JCF,NO,GV,NL,HY,WR,WI,RES,       OPT31190
     1    BB,CC,IFT)                                                    OPT31200
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      IF (IYU.EQ.2) CALL RESID (I,L,N2,JCF,NO,GV,NL,HU,WR,WI,RES,         OPT31210
     1    BB,CC,IFT)                                                      OPT31220
      DO 290 K=1,30                                                       OPT31230
      ZZ=DCMPLX(C.DC,0.D0)                                                OPT31240
      CM=W(K)                                                             OPT31250
      DO 270 II=1,N2                                                      OPT31260
      IF (WI(II)) 27C,25C,26C                                             OPT31270
250   ZD=DCMPLX(-WR(II),OM-WI(II))                                        OPT31280
      ZZ=ZZ+RES(II)/ZD                                                    OPT31290
      GC TO 270                                                           OPT31300
26C   RE=WR(II)                                                           OPT31310
      AI=WI(II)                                                           OPT31320
      ZC=DCMPLX(RE**2 + AI**2 -OM**2,-2.DO*RE*OM)                         OPT31330
      ZN=DCMPLX(RES(II+1)*AI-RES(II)*RE,RES(II)*CM)                       OPT31340
      ZZ=ZZ+ZN/ZC                                                         OPT31350
270   CONTINUE                                                            OPT31360
      IF (IYU .EC. 2 .OR. I .NE. L) GO TC 280                             OPT31370
      PSD(K)=PSD(K)+DN1                                                   OPT31380
2EC   PSD(K)=PSD(K)+DN1*(ZZ*DCONJG(ZZ))                                   OPT31390
29C   CCNTINUE                                                            OPT31400
3C0   CCNTINUE                                                            OPT31410
      IF (IYU .EC. 1) WRITE (6,390) L                                     OPT31420
      IF (IYU .EC. 2) WRITE (6,400) L                                     OPT31430
      WRITE (6,410) (W(I),PSD(I),I=1,30)                                  OPT31440
31C   CONTINUE                                                            OPT31450
      RETURN                                                              OPT31460
320   CONTINUE                                                            OPT31470
      CALL EREXIT (N2,FA,IERR)                                            OPT31480
      RETURN                                                              OPT31490
C-------------------------------------------------------------------------OPT31500
33C   FORMAT (/,41H SUBSEQUENT PSD IS NORMALIZED BY MEAS NO.,I3,//)       OPT31510
340   FORMAT (/,50H SUBSEQUENT PSD IS NORMALIZEC BY PROCESS NOISE NC.,I3OPT31520
     1,//)                                                                OPT31530
350   FORMAT (/38H TRANSFER FUNCTION FROM PROCESS NCISE ,I2,3H TC,13H MEOPT31540
     1ASUREMENT ,I2,//)                                                   OPT31550
36C   FORMAT (/36H TRANSFER FUNCTION FRCM PROCESS NCISE ,I2,3H TC,9H CONOPT31560
     1TROL ,I2,//)                                                        OPT31570
37C   FORMAT (/36H TRANSFER FUNCTION FRCM MEASUREMENT ,I2,16H TO MEASUREOPT31580
     1MENT ,I2,//)                                                        OPT31590
38C   FORMAT (/36H TRANSFER FUNCTION FROM MEASUREMENT ,I2,12H TO CCNTROLOPT31600
     1 ,I2,//)                                                            OPT31610
39C   FORMAT (/14H PSD OF CUTPUT,I3,32H  FORCED BY ALL NCISE-(RAC FREQ,,OPT31620
     115HNORMALIZEC PSD)/)                                                OPT31630
4CC   FORMAT (/15H PSD OF CCNTROL,I3,32H  FORCEC BY ALL NCISE-(RAC FREQ,OPT31640
     1,15HNORMALIZED PSD)/)                                               OPT31650
41C   FORMAT (4(1X,1H(,E11.4,1H,,E11.4,1H)))                              OPT31660
      END                                                                 OPT31670
C======================================================================== OPT31680
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      SUBROUTINE EREXIT (N,A,IERR)
C     EREXIT RETURNS THE NUMBER OF THE EIGENVALUE WHERE HQR2            =
C     FAILS, THEN STOPS THE PROGRAM.                                    =
C=======================================================================
      INTEGER IERR
      DOUBLE PRECISION A
      DIMENSION A(N,N)
      WRITE (5,10) IERR
      CALL RAPRNT (N,N,N,9,A,4,'(9(1X,1PD13.6))')
      RETURN
10    FORMAT (35H FAILURE IN HQR2 ON EIGENVALUE NO. ,I3)
      END
C========================================================================
      SUBROUTINE READF (NS,ISAF,BA)
C     INTERACTIVELY INPUTS THE "F" MATRIX ELEMENT BY ELEMENT.            =
C========================================================================
      REAL*8  BA(NS,NS),DUM,ANSR
      INTEGER I,J,K,L,IANS,ISAF
      DATA IY/'Y'/,IZ/'N'/
      IF (ISAF.EQ.1) GO TO 40
      WRITE (5,130)
      DO 20 I=1,NS
      DO 10 J=1,NS
      WRITE (5,120) I,J
      CALL RDREAL (ANSR)
      BA(I,J)=ANSR
10    CONTINUE
20    CONTINUE
C------------------------------------------------------------------------
30    CALL FRTCMS ('CLRSCRN ')
40    CONTINUE
      WRITE (5,140)
      CALL MATPRT (BA,NS,NS)
50    WRITE (5,150)
      CALL RDCHAR (IANS)
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60
      GO TO 70
60    WRITE (5,160)
      GO TO 50
70    CONTINUE
      IF (IANS.EQ.IZ) GO TO 110
      IF (IANS.EQ.IY) GO TO 80
80    WRITE (5,170)
      CALL RDINT (IANS)
      K=IANS
      WRITE (5,180)
      CALL RDINT (IANS)
      L=IANS
      WRITE (5,12C) K,L                                                 OPT32170
      CALL RCREAL (ANSR)                                                OPT32180
      DUM=ANSR                                                          OPT32190
      DC 100 I=1,NS                                                     OPT32200
      DO 90 J=1,NS                                                      OPT32210
      IF ((I.EQ.K).AND.(J.EQ.L)) BA(I,J)=DUM                            OPT32220
9C    CCNTINUE                                                          OPT32230
10C   CCNTINUE                                                          OPT32240
      GO TO 30                                                          OPT32250
11C   CCNTINUE                                                          OPT32260
      CALL FRTCMS ('CLRSCRN ')                                          OPT32270
      RETURN                                                            OPT32280
C---------------------------------------------------------------------- OPT32290
120   FORMAT (5X,14HTHE ELEMENT F(,I2,1H,,I2,2H)=)                      OPT32300
13C   FORMAT (/,5X,36HENTER THE SYSTEM MATRIX  "F"-MATRIX&,//,10X,41HDIMOPT32310
     1ENSION = # STATES  NS& X # STATES  NS&)                           OPT32320
140   FORMAT (//,15X,33HTHE SYSTEM MATRIX  "F"-MATRIX&...,//)           OPT32330
15C   FORMAT (//5X,54HDO YCU WISH TO CHANGE THE VALUE CF ANY MATRIX ELEMOPT32340
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT32350
160   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT32360
17C   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TC BE CHANGEC.) OPT32370
180   FCRMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT32380
     1.)                                                                OPT32390
      END                                                               OPT32400
C=====================================================================OPT32410
      SUBROUTINE READH (NO,NS,ISAH,HO)                                  OPT32420
C     INTERACTIVELY INPUTS THE "H" MATRIX  MEASUREMENT SCALING MATRIX&.=OPT32430
C=====================================================================OPT32440
      REAL*8  HO(NO,NS),DUM,ANSR                                        OPT32450
      INTEGER IANS,I,J,K,L,ISAH                                         OPT32460
      DATA IY/'Y'/,IZ/'N'/                                              OPT32470
C---------------------------------------------------------------------OPT32480
      IF (ISAH.EC.1) GO TC 40                                           OPT32490
      WRITE (5,12C)                                                     OPT32500
      CO 20 I=1,NC                                                      OPT32510
      DC 10 J=1,NS                                                      OPT32520
      WRITE (5,11C) I,J                                                 OPT32530
      CALL RCREAL (ANSR)                                                OPT32540
      HO(I,J)=ANSR                                                      OPT32550
1C    CCNTINUE                                                          OPT32560
2C    CCNTINUE                                                          OPT32570
C---------------------------------------------------------------------OPT32580
30    CALL FRTCMS ('CLRSCRN ')                                          OPT32590
4C    CCNTINUE                                                          OPT32600
      WRITE (5,13C)                                                     OPT32610
      CALL MATPRT (HO,NO,NS)                                            OPT32620
5C    WRITE (5,14C)                                                     OPT32630
      CALL RDCHAR (IANS)                                                OPT32640
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60
      GO TO 70
60    WRITE (5,150)
      GO TO 50
70    CONTINUE
      IF (IANS.EQ.IZ) GO TO 100
      WRITE (5,160)
      CALL RDINT (IANS)
      K=IANS
      WRITE (5,170)
      CALL RDINT (IANS)
      L=IANS
      WRITE (5,110) K,L
      CALL RDREAL (ANSR)
      DUM=ANSR
      DO 90 I=1,NC
      DO 80 J=1,NS
      IF ((I.EQ.K).AND.(J.EQ.L)) HO(I,J)=DUM
80    CONTINUE
90    CONTINUE
      GO TO 30
100   CONTINUE
      CALL FRTCMS ('CLRSCRN ')
      RETURN
C-----------------------------------------------------------------------
110   FORMAT (5X,14HTHE ELEMENT H(,I2,1H,,I2,2H)=)
120   FORMAT (/,5X,50HENTER THE MEASUREMENT SCALING MATRIX  "H"-MATFIX&.
     1,//,10X,47HDIMENSION = # OBSERVATIONS  NC& X # STATES  NS&)
130   FORMAT (//,10X,46HTHE MEASUREMENT SCALING MATRIX  "H"-MATRIX&...,/
     1/)
140   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEM
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)
150   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)
160   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)
170   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGED
     1)
      END
C=======================================================================
      SUBROUTINE READD (NO,NC,D)
C     INPUTS THE "D" MATRIX  MEASUREMENT FEED-FORWARD DIST. MATRIX&.   =
C=======================================================================
      REAL*8  D(NC,NC),DUM,ANSR
      INTEGER IANS,I,J,K,L
      DATA IY/'Y'/,IZ/'N'/
      WRITE (5,110)
      DO 20 I=1,NC
      DO 10 J=1,NC
      WRITE (5,100) I,J
      CALL RDREAL (ANSR)                                                OPT33130
      D(I,J)=ANSR                                                       OPT33140
 10   CONTINUE                                                          OPT33150
 20   CONTINUE                                                          OPT33160
C-----------------------------------------------------------------------OPT33170
 30   CALL FRTCMS ('CLRSCRN ')                                          OPT33180
      WRITE (5,120)                                                     OPT33190
      CALL MATPRT (D,NO,NC)                                             OPT33200
 40   WRITE (5,130)                                                     OPT33210
      CALL RDCHAR (IANS)                                                OPT33220
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT33230
      GO TO 60                                                          OPT33240
 50   WRITE (5,140)                                                     OPT33250
      GO TO 40                                                          OPT33260
 60   CONTINUE                                                          OPT33270
      IF (IANS.EQ.IZ) GO TO 90                                          OPT33280
      WRITE (5,150)                                                     OPT33290
      CALL RDINT (IANS)                                                 OPT33300
      K=IANS                                                            OPT33310
      WRITE (5,160)                                                     OPT33320
      CALL RDINT (IANS)                                                 OPT33330
      L=IANS                                                            OPT33340
      WRITE (5,100) K,L                                                 OPT33350
      CALL RDREAL (ANSR)                                                OPT33360
      DUM=ANSR                                                          OPT33370
      DO 80 I=1,NO                                                      OPT33380
      DO 70 J=1,NC                                                      OPT33390
      IF ((I.EQ.K).AND.(J.EQ.L)) D(I,J)=DUM                             OPT33400
 70   CONTINUE                                                          OPT33410
 80   CONTINUE                                                          OPT33420
      GO TO 30                                                          OPT33430
 90   CONTINUE                                                          OPT33440
      CALL FRTCMS ('CLRSCRN ')                                          OPT33450
      RETURN                                                            OPT33460
C---------------------------------------------------------------------- OPT33470
100   FORMAT (5X,14HTHE ELEMENT D(,I2,1H,,I2,2H)=)                      OPT33480
110   FORMAT (/,5X,54HENTER THE MEASUREMENT FEEDTHROUGH MATRIX / FEEDFOROPT33490
     1WARD,/,5X,34H DISTRIBUTION MATRIX  "D"-MATRIX&.,//,8X,49HDIMENSIONOPT33500
     2 = # OBSERVATIONS  NO& X # CONTROLS  NC&)                         OPT33510
120   FORMAT (//,5X,50HTHE FEEDFORWARD DISTRIBUTION MATRIX  "C"-MATRIX&.OPT33520
     1.,//)                                                             OPT33530
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT33540
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT33550
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT33560
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT33570
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT33580
     1.)                                                                OPT33590
      END                                                               OPT33600
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C=====================================================================
      SUBROUTINE READG (NS,NC,ISAG,G)
C     INTERACTIVELY INPUTS THE "G" MATRIX  CONTRCL CISTRIBUTICN MATRIX&=
C=====================================================================
      REAL*8  G(NS,NC),DUM,ANSR
      INTEGER IANS,I,J,K,L,ISAG
      CATA IY/'Y'/,IZ/'N'/
      IF (ISAG.EC.1) GO TC 40
      WRITE (5,12C)
      DC 20 I=1,NS
      DO 10 J=1,NC
      WRITE (5,11C) I,J
      CALL RCREAL (ANSR)
      G(I,J)=ANSR
1C    CCNTINUE
2C    CCNTINUE
C--------------------------------------------------------------------
3C    CALL FRTCMS ('CLRSCRN ')
4C    CCNTINUE
      WRITE (5,13C)
      CALL MATPRT (G,NS,NC)
5C    WRITE (5,14C)
      CALL RCCHAR (IANS)
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60
      GO TO 70
6C    WRITE (5,15C)
      GC TO 50
7C    CCNTINUE
      IF (IANS.EC.IZ) GO TC 100
      WRITE (5,16C)
      CALL RCINT (IANS)
      K=IANS
      WRITE (5,17C)
      CALL RDINT (IANS)
      L=IANS
      WRITE (5,11C) K,L
      CALL RCREAL (ANSR)
      DUM=ANSR
      DO 90 I=1,NS
      DC 80 J=1,NC
      IF ((I.EQ.K).AND.(J.EQ.L)) G(I,J)=DUM
80    CCNTINUE
9C    CCNTINUE
      GC TO 30
1CC   CCNTINUE
      CALL FRTCMS ('CLRSCRN ')
      RETURN
C--------------------------------------------------------------------
```

```
110   FORMAT (5X,14HTHE ELEMENT G(,I2,1H,,I2,2H)=)                      OPT34090
120   FORMAT (/,5X,51HENTER THE CONTROL DISTRIBUTION MATRIX  "G"-MATRIX&OPT34100
     1.,//,10X,43HDIMENSION = # STATES  NS& X # CONTROLS  NC&)          OPT34110
130   FORMAT (//,10X,47HTHE CONTROL DISTRIBUTION MATRIX  "G"-MATRIX&...,OPT34120
     1//)                                                               OPT34130
140   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT34140
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT34150
150   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT34160
160   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT34170
170   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT34180
     1.)                                                                OPT34190
      END                                                               OPT34200
C=======================================================================OPT34210
      SUBROUTINE READFB (NC,NS,FBGC)                                    OPT34220
C     INPUTS THE "C"     FEEDBACK GAIN CONTROL MATRIX&.                =OPT34230
C=======================================================================OPT34240
      REAL*8  FBGC(NC,NS),DUM,ANSR                                      OPT34250
      INTEGER IANS,I,J,K,L                                              OPT34260
      DATA IY/'Y'/,IZ/'N'/                                              OPT34270
      WRITE (5,110)                                                     OPT34280
      DO 20 I=1,NC                                                      OPT34290
      DO 10 J=1,NS                                                      OPT34300
      WRITE (5,100) I,J                                                 OPT34310
      CALL RDREAL (ANSR)                                                OPT34320
      FBGC(I,J)=ANSR                                                    OPT34330
10    CONTINUE                                                          OPT34340
20    CONTINUE                                                          OPT34350
C-----------------------------------------------------------------------OPT34360
30    CALL FRTCMS ('CLRSCRN ')                                          OPT34370
      WRITE (5,120)                                                     OPT34380
      CALL MATPRT (FBGC,NC,NS)                                          OPT34390
40    WRITE (5,130)                                                     OPT34400
      CALL RDCHAR (IANS)                                                OPT34410
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT34420
      GO TO 60                                                          OPT34430
50    WRITE (5,140)                                                     OPT34440
      GO TO 40                                                          OPT34450
60    CONTINUE                                                          OPT34460
      IF (IANS.EQ.IZ) GO TO 90                                          OPT34470
      WRITE (5,150)                                                     OPT34480
      CALL RDINT (IANS)                                                 OPT34490
      K=IANS                                                            OPT34500
      WRITE (5,160)                                                     OPT34510
      CALL RDINT (IANS)                                                 OPT34520
      L=IANS                                                            OPT34530
      WRITE (5,100) K,L                                                 OPT34540
      CALL RDREAL (ANSR)                                                OPT34550
      DUM=ANSR                                                          OPT34560
      DO 80 I=1,NC                                                      OPT34570
      DO 70 J=1,NS                                                      OPT34580
      IF ((I.EQ.K).AND.(J.EQ.L)) FBGC(I,J)=DUM                          OPT34590
70    CONTINUE                                                          OPT34600
80    CONTINUE                                                          OPT34610
      GO TO 30                                                          OPT34620
90    CONTINUE                                                          OPT34630
      CALL FRTCMS ('CLRSCRN ')                                          OPT34640
      RETURN                                                            OPT34650
C----------------------------------------------------------------------- OPT34660
100   FORMAT (5X,14HTHE ELEMENT C(,I2,1H,,I2,2H)=)                      OPT34670
110   FORMAT (/,5X,52HENTER THE FEEDBACK GAIN CONTROL MATRIX  "C"-MATRIXOPT34680
     1&.,//,10X,44HDIMENSION = # CONTROLS  NC& X # STATES  NS&.)        OPT34690
120   FORMAT (//,10X,45HTHE FEEDBACK GAIN CONTROL MATRIX  "C"-MATRIX&,//OPT34700
     1)                                                                 OPT34710
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT34720
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT34730
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY    ENTER "YES" OR "NO".)OPT34740
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT34750
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT34760
     1.)                                                                OPT34770
      END                                                               OPT34780
C=======================================================================OPT34790
      SUBROUTINE READAY (NC,ISAA,AY)                                    OPT34800
C     INPUTS THE "A" MATRIX   DIAGONAL OUTPUT COST MATRIX&.            =OPT34810
C=======================================================================OPT34820
      REAL*8  AY(NO,NO),DUM,ANSR                                        OPT34830
      INTEGER IANS,I,J,K,L                                              OPT34840
      DATA IY/'Y'/,IZ/'N'/                                              OPT34850
      IF (ISAA.EQ.1) GO TO 30                                           OPT34860
      WRITE (5,110)                                                     OPT34870
      DO 20 I=1,NC                                                      OPT34880
      DO 10 J=1,NC                                                      OPT34890
      WRITE (5,100) I,J                                                 OPT34900
      CALL RDREAL (ANSR)                                                OPT34910
      AY(I,J)=ANSR                                                      OPT34920
10    CONTINUE                                                          OPT34930
20    CONTINUE                                                          OPT34940
C-----------------------------------------------------------------------OPT34950
30    CALL FRTCMS ('CLRSCRN ')                                          OPT34960
      WRITE (5,120)                                                     OPT34970
      CALL MATPRT (AY,NO,NC)                                            OPT34980
40    WRITE (5,130)                                                     OPT34990
      CALL RDCHAR (IANS)                                                OPT35000
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT35010
      GO TO 60                                                          OPT35020
50    WRITE (5,140)                                                     OPT35030
      GO TO 40                                                          OPT35040
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60     CONTINUE                                                         OPT35050
       IF (IANS.EQ.IZ) GO TO 90                                         OPT35060
       WRITE (5,150)                                                    OPT35070
       CALL RDINT (IANS)                                                OPT35080
       K=IANS                                                           OPT35090
       WRITE (5,160)                                                    OPT35100
       CALL RDINT (IANS)                                                OPT35110
       L=IANS                                                           OPT35120
       WRITE (5,100) K,L                                                OPT35130
       CALL RDREAL (ANSR)                                               OPT35140
       DUM=ANSR                                                         OPT35150
       DO 80 I=1,NC                                                     OPT35160
       DO 70 J=1,NC                                                     OPT35170
       IF ((I.EQ.K).AND.(J.EQ.L)) AY(I,J)=DUM                           OPT35180
70     CONTINUE                                                         OPT35190
80     CONTINUE                                                         OPT35200
       GO TO 30                                                         OPT35210
90     CONTINUE                                                         OPT35220
       CALL FRTCMS ('CLRSCRN ')                                         OPT35230
       RETURN                                                           OPT35240
C----------------------------------------------------------------------- OPT35250
100    FORMAT (5X,14HTHE ELEMENT A(,I2,1H,,I2,2H)=)                     OPT35260
110    FORMAT (//,5X,54HENTER THE OUTPUT MEASUREMENT COST MATRIX  "A"-MATOPT35270
      1RIX&.,/,5X,53HDIMENSION = # OBSERVATIONS  NO& X # OBSERVATIONS  NOOPT35280
      2&)                                                               OPT35290
120    FORMAT (//,5X,50HTHE OUTPUT MEASUREMENT COST MATRIX  "A"-MATRIX&..OPT35300
      1.,//)                                                            OPT35310
130    FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT35320
      1ENT?,//,10X,19HTYPE "YES" OR "NO".)                              OPT35330
140    FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT35340
150    FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT35350
160    FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT35360
      1.)                                                               OPT35370
       END                                                              OPT35380
C=======================================================================OPT35390
       SUBROUTINE READB (NC,ISAB,B)                                     OPT35400
C      INPUTS THE "B" MATRIX  CONTROL COST WEIGHTING MATRIX&.          =OPT35410
C=======================================================================OPT35420
       REAL*8  B(NC,NC),DUM,ANSR                                        OPT35430
       INTEGER IANS,I,J,K,L                                             OPT35440
       DATA IY/'Y'/,IZ/'N'/                                             OPT35450
       IF (ISAB.EQ.1) GO TO 20                                          OPT35460
       WRITE (5,90)                                                     OPT35470
       DO 10 I=1,NC                                                     OPT35480
       DO 10 J=1,NC                                                     OPT35490
       WRITE (5,80) I,J                                                 OPT35500
       CALL RDREAL (ANSR)                                               OPT35510
10     B(I,J)=ANSR                                                      OPT35520
```

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C-----------------------------------------------------------------------OPT35530
20      CALL FRTCMS ('CLRSCRN ')                                        OPT35540
        WRITE (5,100)                                                   OPT35550
        CALL MATPRT (B,NC,NC)                                           OPT35560
30      WRITE (5,110)                                                   OPT35570
        CALL RDCHAR (IANS)                                              OPT35580
        IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                     OPT35590
        GO TO 50                                                        OPT35600
40      WRITE (5,120)                                                   OPT35610
        GO TO 30                                                        OPT35620
50      CONTINUE                                                        OPT35630
        IF (IANS.EQ.IZ) GO TO 70                                        OPT35640
        WRITE (5,130)                                                   OPT35650
        CALL RDINT (IANS)                                               OPT35660
        K=IANS                                                          OPT35670
        WRITE (5,140)                                                   OPT35680
        CALL RDINT (IANS)                                               OPT35690
        L=IANS                                                          OPT35700
        WRITE (5,80) K,L                                                OPT35710
        CALL RDREAL (ANSR)                                              OPT35720
        DUM=ANSR                                                        OPT35730
        DO 60 I=1,NC                                                    OPT35740
        DO 60 J=1,NC                                                    OPT35750
        IF ((I.EQ.K).AND.(J.EQ.L)) B(I,J)=DUM                           OPT35760
60      CONTINUE                                                        OPT35770
        GO TO 20                                                        OPT35780
70      CONTINUE                                                        OPT35790
        CALL FRTCMS ('CLRSCRN ')                                        OPT35800
        RETURN                                                          OPT35810
C---------------------------------------------------------------------- OPT35820
80      FORMAT (5X,14HTHE ELEMENT B(,I2,1H,,I2,2H)=)                    OPT35830
90      FORMAT (/,5X,52HENTER THE CONTROL COST WEIGHTING MATRIX  "B"-MATRIOPT35840
       1X&,/,10X,45HDIMENSION = # CONTROLS  NC& X # CONTROLS  NC&)      OPT35850
100     FORMAT (//,10X,37HTHE CONTROL COST MATRIX..........B...,//)     OPT35860
110     FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT35870
       1ENT?,//,10X,19HTYPE "YES" OR "NO".)                             OPT35880
120     FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT35890
130     FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT35900
140     FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT35910
       1)                                                               OPT35920
        END                                                             OPT35930
C=======================================================================OPT35940
        SUBROUTINE READG2 (NS,NG,IGAM,GAM)                              OPT35950
C       INPUTS THE "GAM" MATRIX  PROCESS NOISE DISTRIBUTION MATRIX&.   =OPT35960
C=======================================================================OPT35970
        REAL*8  GAM(NS,NG),DUM,ANSR                                     OPT35980
        INTEGER IANS,I,J,K,L,IGAM                                       OPT35990
        DATA IY/'Y'/,IZ/'N'/                                            OPT36000
```

```
      IF (IGAM.EQ.1) GO TO 40                                           OPT36010
      WRITE (5,120)                                                     OPT36020
      DO 20 I=1,NS                                                      OPT36030
      DO 10 J=1,NG                                                      OPT36040
      WRITE (5,110) I,J                                                 OPT36050
      CALL RDREAL (ANSR)                                                OPT36060
      GAM(I,J)=ANSR                                                     OPT36070
10    CONTINUE                                                          OPT36080
20    CONTINUE                                                          OPT36090
C-----------------------------------------------------------------------OPT36100
30    CALL FRTCMS ('CLRSCRN ')                                          OPT36110
40    CONTINUE                                                          OPT36120
      WRITE (5,130)                                                     OPT36130
      CALL MATPRT (GAM,NS,NG)                                           OPT36140
50    WRITE (5,140)                                                     OPT36150
      CALL RDCHAR (IANS)                                                OPT36160
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                       OPT36170
      GO TO 70                                                          OPT36180
60    WRITE (5,150)                                                     OPT36190
      GO TO 50                                                          OPT36200
70    CONTINUE                                                          OPT36210
      IF (IANS.EQ.IZ) GO TO 100                                         OPT36220
      WRITE (5,160)                                                     OPT36230
      CALL RDINT (IANS)                                                 OPT36240
      K=IANS                                                            OPT36250
      WRITE (5,170)                                                     OPT36260
      CALL RDINT (IANS)                                                 OPT36270
      L=IANS                                                            OPT36280
      WRITE (5,110) K,L                                                 OPT36290
      CALL RDREAL (ANSR)                                                OPT36300
      DUM=ANSR                                                          OPT36310
      DO 90 I=1,NS                                                      OPT36320
      DO 80 J=1,NG                                                      OPT36330
      IF ((I.EQ.K).AND.(J.EQ.L)) GAM(I,J)=DUM                           OPT36340
80    CONTINUE                                                          OPT36350
90    CONTINUE                                                          OPT36360
      GO TO 30                                                          OPT36370
100   CONTINUE                                                          OPT36380
      CALL FRTCMS ('CLRSCRN ')                                          OPT36390
      RETURN                                                            OPT36400
C---------------------------------------------------------------------- OPT36410
110   FORMAT (5X,16HTHE ELEMENT GAM(,I2,1H,,I2,2H)=)                    OPT36420
120   FORMAT (/,5X,36HENTER THE PROCESS NOISE DISTRIBUTION,/,5X,24HMATRIOPT36430
     1X  "GAMMA"-MATRIX&.,/,2X,56HDIMENSION = # STATES  NS& X # PROCESS OPT36440
     2NOISE SOURCES  NG&)                                               OPT36450
130   FORMAT (//,10X,37HTHE PROCESS NOISE DISTRIBUTION MATRIX,/,10X,19H OPT36460
     1"GAMMA"-MATRIX&...,//)                                            OPT36470
140   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT36480
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT36490
150   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT36500
160   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TC BE CHANGED.) OPT36510
170   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT36520
     1.)                                                                OPT36530
      END                                                               OPT36540
C=======================================================================OPT36550
      SUBROUTINE READQ (NG,Q)                                           OPT36560
C     INTERACTIVELY INPUTS THE "Q" MATRIX  NOISE WEIGHTING MATRIX&     =OPT36570
C=======================================================================OPT36580
      REAL*8  Q(NG,NG),DUM,ANSR                                         OPT36590
      INTEGER IANS,I,J,K,L                                              OPT36600
      DATA IY/'Y'/,IZ/'N'/                                              OPT36610
      WRITE (5,110)                                                     OPT36620
      DC 20 I=1,NG                                                      OPT36630
      DC 10 J=1,NG                                                      OPT36640
      WRITE (5,100) I,J                                                 OPT36650
      CALL RDREAL (ANSR)                                                OPT36660
      Q(I,J)=ANSR                                                       OPT36670
10    CONTINUE                                                          OPT36680
20    CONTINUE                                                          OPT36690
C-----------------------------------------------------------------------OPT36700
30    CALL FRTCMS ('CLRSCRN ')                                          OPT36710
      WRITE (5,120)                                                     OPT36720
      CALL MATPRT (Q,NG,NG)                                             OPT36730
40    WRITE (5,130)                                                     OPT36740
      CALL RDCHAR (IANS)                                                OPT36750
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT36760
      GO TO 60                                                          OPT36770
50    WRITE (5,140)                                                     OPT36780
      GO TO 40                                                          OPT36790
60    CONTINUE                                                          OPT36800
      IF (IANS.EQ.IZ) GO TC 90                                          OPT36810
      WRITE (5,150)                                                     OPT36820
      CALL RDINT (IANS)                                                 OPT36830
      K=IANS                                                            OPT36840
      WRITE (5,160)                                                     OPT36850
      CALL RDINT (IANS)                                                 OPT36860
      L=IANS                                                            OPT36870
      WRITE (5,100) K,L                                                 OPT36880
      CALL RDREAL (ANSR)                                                OPT36890
      DUM=ANSR                                                          OPT36900
      DC 80 I=1,NG                                                      OPT36910
      DO 70 J=1,NG                                                      OPT36920
      IF ((I.EQ.K).AND.(J.EQ.L)) Q(I,J)=DUM                             OPT36930
70    CONTINUE                                                          OPT36940
80    CONTINUE                                                          OPT36950
      GO TO 30                                                          OPT36960
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90    CONTINUE                                                          OPT36970
      CALL FRTCMS ('CLRSCRN ')                                          OPT36980
      RETURN                                                            OPT36990
C---------------------------------------------------------------------- OPT37000
100   FORMAT (5X,14HTHE ELEMENT Q(,I2,1H,,I2,2H)=)                      OPT37010
110   FORMAT (//,5X,44HENTER THE PROCESS NOISE PSD WEIGHTING MATRIX,/,5XOPT37020
     1,12H "Q"MATRIX&.,//,5X,42HDIMENSION = # PROCESS NOISE SOURCES  NG&OPT37030
     2 X,/,17X,27H#PROCESS NOISE SOURCES  NG&)                          OPT37040
120   FORMAT (//,5X,42HTHE PROCESS NOISE WEIGHTING MATRIX.....Q..,//)   OPT37050
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT37060
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT37070
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT37080
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT37090
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT37100
     1.)                                                                OPT37110
      END                                                               OPT37120
C======================================================================OPT37130
      SUBROUTINE READR (NC,RC)                                          OPT37140
C     INTERACTIVELY INPUTS THE "R" MATRIX=                              OPT37150
C      MEASUREMENT NOISE DISTRIBUTION MATRIX.&                         =OPT37160
C======================================================================OPT37170
      REAL*8  RC(NO,NO),DUM,ANSR                                        OPT37180
      INTEGER IANS,I,J,K,L                                              OPT37190
      DATA IY/'Y'/,IZ/'N'/                                              OPT37200
      WRITE (5,90)                                                      OPT37210
      DO 10 I=1,NC                                                      OPT37220
      DO 10 J=1,NC                                                      OPT37230
      WRITE (5,80) I,J                                                  OPT37240
      CALL RDREAL (ANSR)                                                OPT37250
10    RC(I,J)=ANSR                                                      OPT37260
C----------------------------------------------------------------------OPT37270
20    CALL FRTCMS ('CLRSCRN ')                                          OPT37280
      WRITE (5,100)                                                     OPT37290
      CALL MATPRT (RC,NO,NC)                                            OPT37300
30    WRITE (5,110)                                                     OPT37310
      CALL RDCHAR (IANS)                                                OPT37320
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                       OPT37330
      GO TO 50                                                          OPT37340
40    WRITE (5,120)                                                     OPT37350
      GO TO 30                                                          OPT37360
50    CONTINUE                                                          OPT37370
      IF (IANS.EQ.IZ) GO TO 70                                          OPT37380
      WRITE (5,130)                                                     OPT37390
      CALL RDINT (IANS)                                                 OPT37400
      K=IANS                                                            OPT37410
      WRITE (5,140)                                                     OPT37420
      CALL RDINT (IANS)                                                 OPT37430
      L=IANS                                                            OPT37440
      WRITE (5,80) K,L                                                  OPT37450
      CALL RDREAL (ANSR)                                                OPT37460
      DUM=ANSR                                                          OPT37470
      DO 60 I=1,NC                                                      OPT37480
      DO 60 J=1,NC                                                      OPT37490
60    IF ((I.EQ.K).AND.(J.EQ.L)) RC(I,J)=DUM                            OPT37500
      GO TO 20                                                          OPT37510
70    CONTINUE                                                          OPT37520
      CALL FRTCMS ('CLRSCRN ')                                          OPT37530
      RETURN                                                            OPT37540
C---------------------------------------------------------------------- OPT37550
80    FORMAT (5X,14HTHE ELEMENT R(,I2,1H,,I2,2H)=)                      OPT37560
90    FORMAT (/,5X,60HENTER THE MEASUREMENT NOISE DISTRIBUTION MATRIX  "OPT37570
     1R"MATRIX&.,//,5X,53HDIMENSION = # OBSERVATIONS  NO& X # OBSERVATIOPT37580
     2NS  NO&)                                                          OPT37590
100   FORMAT (//,15X,50HTHE MEASUREMENT NOISE DISTRIBUTION MATRIX.....R.OPT37600
     1..,//)                                                            OPT37610
110   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT37620
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT37630
120   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY    ENTER "YES" OR "NO".)OPT37640
130   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT37650
140   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT37660
     1)                                                                 OPT37670
      END                                                               OPT37680
C=======================================================================OPT37690
      SUBROUTINE READFE (NS,NO,FBGE)                                    OPT37700
C     INTERACTIVELY INPUTS THE "K"  FEEDBACK GAIN ESTIMATOR MATRIX&    =OPT37710
C=======================================================================OPT37720
      REAL*8  FBGE(NS,NO),DUM,ANSR                                      OPT37730
      INTEGER IANS,I,J,K,L                                              OPT37740
      DATA IY/'Y'/,IZ/'N'/                                              OPT37750
      WRITE (5,110)                                                     OPT37760
      DO 20 I=1,NS                                                      OPT37770
      DO 10 J=1,NO                                                      OPT37780
      WRITE (5,100) I,J                                                 OPT37790
      CALL RDREAL (ANSR)                                                OPT37800
      FBGE(I,J)=ANSR                                                    OPT37810
10    CONTINUE                                                          OPT37820
20    CONTINUE                                                          OPT37830
C-----------------------------------------------------------------------OPT37840
30    CALL FRTCMS ('CLRSCRN ')                                          OPT37850
      WRITE (5,120)                                                     OPT37860
      CALL MATPRT (FBGE,NS,NO)                                          OPT37870
40    WRITE (5,130)                                                     OPT37880
      CALL RDCHAR (IANS)                                                OPT37890
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT37900
      GO TO 60                                                          OPT37910
50    WRITE (5,140)                                                     OPT37920
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      GO TO 40
60    CCNTINUE
      IF (IANS.EC.IZ) GC TC 90
      WRITE (5,1EC)
      CALL RCINT (IANS)
      K=IANS
      WRITE (5,16C)
      CALL RCINT (IANS)
      L=IANS
      WRITE (5,10C) K,L
      CALL RDREAL (ANSR)
      DUM=ANSR
      CO 80 I=1,NS
      DO 70 J=1,NC
      IF ((I.EQ.K).AND.(J.EQ.L)) FBGE(I,J)=DUM
7C    CCNTINUE
80    CCNTINUE
      GC TO 30
9C    CCNTINUE
      CALL FRTCMS ('CLRSCRN ')
      RETURN
C-----------------------------------------------------------------------
100   FCRMAT (5X,14HTHE ELEMENT K(,I2,1H,,I2,2H)=)
110   FORMAT (/,5X,54HENTER THE FEEDBACK GAIN ESTIMATOR MATRIX  "K"-MATR
     1IX&.,//,10X,48HDIMENSICN = # STATES  NS& X # CBSERVATICNS  NC&.)
120   FORMAT (//,15X,47HTHE FEEDBACK GAIN ESTIMATOR MATRIX  "K"-MATRIX&,
     1//)
130   FCRMAT (//,5X,54HDC YOU WISH TO CHANGE THE VALUE CF ANY MATRIX ELE
     1MENT?,//,10X,19HTYPE "YES" OR "NO".)
14C   FORMAT (1X,51HWARNING: IMPROPER CATA ENTRY   ENTER "YES" CR "NO".)
15C   FCRMAT (5X,5CHENTER THE ROW NUMBER OF THE ELEMENT TC BE CHANGED.)
160   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGED
     1)
      END
C=======================================================================
      SUBROUTINE READW (NG,WR)
C     INTERACTIVELY INPUTS THE "WO" MATRIX  STEADY CISTURBANCE VECTCR =
C     MATRIX& ELEMENT BY ELEMENT.                                      =
C=======================================================================
      REAL*8  WR(NG),DUM,ANSR
      INTEGER IANS,I,K
      CATA IY/'Y'/,IZ/'N'/
      WRITE (5,1CC)
      CC 10 I=1,NG
      WRITE (5,80) I
      CALL RDREAL (ANSR)
      WR(I)=ANSR
1C    CCNTINUE
```

```
C-----------------------------------------------------------------------OPT38410
20    CALL FRTCMS ('CLRSCRN ')                                           OPT38420
      WRITE (5,110)                                                      OPT38430
      WRITE (5,90) (WR(I),I=1,NG)                                        OPT38440
30    WRITE (5,120)                                                      OPT38450
      CALL RDCHAR (IANS)                                                 OPT38460
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                        OPT38470
      GO TO 50                                                           OPT38480
40    WRITE (5,130)                                                      OPT38490
      GO TO 30                                                           OPT38500
50    CONTINUE                                                           OPT38510
      IF (IANS.EQ.IZ) GO TO 70                                           OPT38520
      WRITE (5,140)                                                      OPT38530
      CALL RDINT (IANS)                                                  OPT38540
      K=IANS                                                             OPT38550
      WRITE (5,80) K                                                     OPT38560
      CALL RDREAL (ANSR)                                                 OPT38570
      DUM=ANSR                                                           OPT38580
      DO 60 I=1,NG                                                       OPT38590
      IF (I.EQ.K) WR(I)=DUM                                              OPT38600
60    CONTINUE                                                           OPT38610
      GO TO 20                                                           OPT38620
70    CONTINUE                                                           OPT38630
      CALL FRTCMS ('CLRSCRN ')                                           OPT38640
      RETURN                                                             OPT38650
C---------------------------------------------------------------------- OPT38660
80    FORMAT (5X,15HTHE ELEMENT WO(,I2,2H)=)                             OPT38670
90    FORMAT (F12.5)                                                     OPT38680
100   FORMAT (/,5X,57HENTER THE STEADY DISTURBANCE VECTOR MATRIX  "WO"-MOPT38690
     1ATRIX&.,//,10X,44HDIMENSION = # PROCESS NOISE SOURCES  NG& X 1)   OPT38700
110   FORMAT (//,15X,53HTHE STEADY DISTURBANCE VECTOR MATRIX  "WO"-MATRIOPT38710
     1X&...,//)                                                          OPT38720
120   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT38730
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                                OPT38740
130   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT38750
140   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT38760
      END                                                                OPT38770
C=======================================================================OPT38780
C  SUBROUTINE RDREAL -- INTERACTIVELY READS A REAL NUMBER REPLY        =OPT38790
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL    =OPT38800
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.               =OPT38810
C=======================================================================OPT38820
      SUBROUTINE RDREAL (ANSR)                                           OPT38830
      REAL*8 ANSR                                                        OPT38840
      INTEGER COUNT                                                      OPT38850
C-----------------------------------------------------------------------OPT38860
      COUNT=0                                                            OPT38870
10    CONTINUE                                                           OPT38880
```

```
      CCUNT=COUNT+1                                                     OPT38890
      IF (COLNT.LT.3) GO TC 20                                          OPT38900
      WRITE (5,6C)                                                      OPT38910
      GC TO 40                                                          OPT38920
2C    CCNTINUE                                                          OPT38930
      READ (5,*,END=30,ERR=30) ANSR                                     OPT38940
      RETURN                                                            OPT38950
3C    REWIND 5                                                          OPT38960
      WRITE (5,50)                                                      OPT38970
      GO TO 10                                                          OPT38980
4C    CCNTINUE                                                          OPT38990
      STOP                                                              OPT39000
C-----------------------------------------------------------------------OPT39010
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NCT ALLCWED, ENTER A NUMEOPT39020
     1RICAL VALUE.)                                                     OPT39030
6C    FORMAT (///,5X,47HPRCGRAM TERMINATICN - TWC NULL STRINGS ENTERED )OPT39040
      END                                                               OPT39050
C=======================================================================OPT39060
C  SLBRCUTINE RDINT -- INTERACTIVELY READS AN INTEGER REPLY            =OPT39070
C  INTC A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS AN IMPRCPER=OPT39080
C  CATA CHARACTER THE S/R ISSUES A WARNING ANC ALLCWS A RECOVERY.      =OPT39090
C=======================================================================OPT39100
      SUBROUTINE RDINT (IANS)                                           OPT39110
      INTEGER CCUNT,IANS                                                OPT39120
C-----------------------------------------------------------------------OPT39130
      CCUNT=0                                                           OPT39140
1C    CCNTINUE                                                          OPT39150
      CCUNT=COUNT+1                                                     OPT39160
      IF (COUNT.LT.3) GO TC 20                                          OPT39170
      WRITE (5,6C)                                                      OPT39180
      GO TO 50                                                          OPT39190
2C    CCNTINUE                                                          OPT39200
      READ (5,*,END=40,ERR=40) IANS                                     OPT39210
      IF (IANS) 4C,40,30                                                OPT39220
3C    CCNTINUE                                                          OPT39230
      RETURN                                                            OPT39240
4C    REWIND 5                                                          OPT39250
      WRITE (5,7C)                                                      OPT39260
      GC TO 10                                                          OPT39270
5C    CCNTINUE                                                          OPT39280
      STOP                                                              OPT39290
C-----------------------------------------------------------------------OPT39300
6C    FORMAT (//,5X,49HPROGRAM TERMINATION - TWO IMPRCPER DATA ENTRIES  OPT39310
     1)                                                                 OPT39320
7C    FORMAT (1X,56HWARNING: IMPROPER DATA ENTRY   ENTER A POSITIVE INTEOPT39330
     1GER.)                                                             OPT39340
      END                                                               OPT39350
C=======================================================================OPT39360
```

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C  SUBROUTINE RDCHAR -- INTERACTIVELY READS A CHARACTER STRING REPLY   =OPT39370
C  ('YES' OR 'NO') INTO A FORTRAN PROGRAM. IF THE USER INADVERTENLY    =OPT39380
C  ENTERS  A NULL STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY=OPT39390
C=====================================================================OPT39400
      SUBROUTINE RDCHAR (IANS)                                          OPT39410
      INTEGER COUNT,IANS                                                OPT39420
C     DATA IY/'Y'/,IZ/'N'/                                              OPT39430
C---------------------------------------------------------------------OPT39440
      COUNT=0                                                           OPT39450
10    CONTINUE                                                          OPT39460
      COUNT=COUNT+1                                                     OPT39470
      IF (COUNT.LT.3) GO TO 20                                          OPT39480
      WRITE (5,60)                                                      OPT39490
      GO TO 40                                                          OPT39500
20    CONTINUE                                                          OPT39510
      REWIND 5                                                          OPT39520
      READ (5,70,END=30,ERR=30) IANS                                    OPT39530
      RETURN                                                            OPT39540
30    REWIND 5                                                          OPT39550
      WRITE (5,50)                                                      OPT39560
      GO TO 10                                                          OPT39570
40    CONTINUE                                                          OPT39580
      STOP                                                              OPT39590
C---------------------------------------------------------------------OPT39600
50    FORMAT (1X,60HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER "YES" OPT39610
     1OR "NO".)                                                         OPT39620
60    FORMAT (///,5X,47HPROGRAM TERMINATION - TWO NULL STRINGS ENTERED )OPT39630
70    FORMAT (A1)                                                       OPT39640
      END                                                               OPT39650
C=====================================================================OPT39660
C  SUBROUTINE MATPRT -- DISPLAYS A TWO-DIMENSIONAL ARRAY (16 COLS. MAX)=OPT39670
C  IN VARIABLE SCREEN FORMAT FOR USER EASE IN ROW IDENTIFICATION.      =OPT39680
C=====================================================================OPT39690
      SUBROUTINE MATPRT (PRTT,NROW,NCOL)                                OPT39700
      IMPLICIT REAL*8 (A-H,O-Z)                                         OPT39710
      DIMENSION PRTT(NROW,NCOL)                                         OPT39720
C---------------------------------------------------------------------OPT39730
      IF (NCOL.EQ.0)  NCOL=1                                            OPT39740
      IF (NCOL.EQ.1)  WRITE (5,10)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39750
      IF (NCOL.EQ.2)  WRITE (5,20)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39760
      IF (NCOL.EQ.3)  WRITE (5,30)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39770
      IF (NCOL.EQ.4)  WRITE (5,40)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39780
      IF (NCOL.EQ.5)  WRITE (5,50)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39790
      IF (NCOL.EQ.6)  WRITE (5,60)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39800
      IF (NCOL.EQ.7)  WRITE (5,70)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39810
      IF (NCOL.EQ.8)  WRITE (5,80)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39820
      IF (NCOL.EQ.9)  WRITE (5,90)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39830
      IF (NCOL.EQ.10) WRITE (5,100) ((PRTT(I,J),J=1,NCOL),I=1,NROW)     OPT39840
      IF (NCOL.EQ.11) WRITE (5,110) ((PRTT(I,J),J=1,NCOL),I=1,NROW)       OPT39850
      IF (NCOL.EQ.12) WRITE (5,120) ((PRTT(I,J),J=1,NCOL),I=1,NROW)       OPT39860
      IF (NCOL.EQ.13) WRITE (5,130) ((PRTT(I,J),J=1,NCOL),I=1,NROW)       OPT39870
      IF (NCOL.EQ.14) WRITE (5,140) ((PRTT(I,J),J=1,NCOL),I=1,NROW)       OPT39880
      IF (NCOL.EQ.15) WRITE (5,150) ((PRTT(I,J),J=1,NCOL),I=1,NROW)       OPT39890
      IF (NCOL.EQ.16) WRITE (5,160) ((PRTT(I,J),J=1,NCOL),I=1,NRCW)       OPT39900
      RETURN                                                              OPT39910
C----------------------------------------------------------------------- OPT39920
10    FORMAT (F12.5)                                                      OPT39930
20    FORMAT (2F12.5)                                                     OPT39940
30    FORMAT (3F12.5)                                                     OPT39950
40    FORMAT (4F12.5)                                                     OPT39960
50    FORMAT (5F12.5)                                                     OPT39970
60    FORMAT (6F12.5)                                                     OPT39980
70    FORMAT (6F12.5,/,F12.5,//)                                          OPT39990
80    FORMAT (6F12.5,/,2F12.5,//)                                         OPT40000
90    FORMAT (6F12.5,/,3F12.5,//)                                         OPT40010
100   FORMAT (6F12.5,/,4F12.5,//)                                         OPT40020
110   FORMAT (6F12.5,/,5F12.5,//)                                         OPT40030
120   FORMAT (6F12.5,/,6F12.5,//)                                         OPT40040
130   FORMAT (6F12.5,/,6F12.5,/,F12.5,//)                                 OPT40050
140   FORMAT (6F12.5,/,6F12.5,/,2F12.5,//)                                OPT40060
150   FORMAT (6F12.5,/,6F12.5,/,3F12.5,//)                                OPT40070
160   FORMAT (6F12.5,/,6F12.5,/,4F12.5,//)                                OPT40080
      END                                                                 OPT40090
C=======================================================================OPT40100
C  SUBROUTINE RDMATF -- READS THE FLAGS AND MATRIX SIZES FROM          =OPT40110
C  THE DATA FILE ON FILEDEF 9.  ASKS IF YOU WANT TO USE THE MATRICES.  =OPT40120
C=======================================================================OPT40130
      SUBROUTINE RDMATF (NS,NC,NOB,NG,ISAF,ISAG,ISAH,IGAM,ISAA,ISAB,IRDMOPT40140
     1AT)                                                                 OPT40150
      DATA IYES/'Y'/,INO/'N'/                                             OPT40160
C     INTEGER NS,NC,NOB,NG,ISAF,ISAG,ISAH,IGAM,IRDMAT,INO,IANS,K          OPT40170
      REWIND 9                                                            OPT40180
      READ (9,240,END=30,ERR=30) K,IANS                                   OPT40190
      IF (IANS.EQ.1) GO TO 10                                             OPT40200
      GO TO 30                                                            OPT40210
10    READ (9,250) NS,NC,NOB,NG                                           OPT40220
      WRITE (5,255)                                                       OPT40230
      CALL FRTCMS ('CLRSCRN ')                                            OPT40240
20    WRITE (5,260)                                                       OPT40250
      CALL RDINT (IANS)                                                   OPT40260
      IF (IANS.GT.3) GO TO 20                                             OPT40270
      IF (IANS.EQ.3) GO TO 30                                             OPT40280
      IRDMAT=1                                                            OPT40290
      IF (IANS.EQ.2) GO TO 40                                             OPT40300
      ISAF=1                                                              OPT40310
      ISAG=1                                                              OPT40320
      ISAH=1                                                            OPT40330
      IGAM=1                                                            OPT40340
      ISAA=1                                                            OPT40350
      ISAB=1                                                            OPT40360
30    RETURN                                                            OPT40370
C-----------------------------------------------ISAF--------------------OPT40380
40    CALL FRTCMS ('CLRSCRN ')                                          OPT40390
50    WRITE (5,270)                                                     OPT40400
      CALL RDCHAR (IANS)                                                OPT40410
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 70                     OPT40420
60    WRITE (5,330)                                                     OPT40430
      GO TO 50                                                          OPT40440
70    CONTINUE                                                          OPT40450
      IF (IANS.EQ.IYES) ISAF=1                                          OPT40460
      IF (IANS.EQ.INO) ISAF=0                                           OPT40470
C-----------------------------------------------ISAH--------------------OPT40480
      IF (NOB.EQ.0) GO TO 110                                           OPT40490
      CALL FRTCMS ('CLRSCRN ')                                          OPT40500
80    WRITE (5,280)                                                     OPT40510
      CALL RDCHAR (IANS)                                                OPT40520
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 100                    OPT40530
90    WRITE (5,330)                                                     OPT40540
      GO TO 80                                                          OPT40550
100   CONTINUE                                                          OPT40560
      IF (IANS.EQ.IYES) ISAH=1                                          OPT40570
      IF (IANS.EQ.INO) ISAH=0                                           OPT40580
110   CONTINUE                                                          OPT40590
C-----------------------------------------------ISAG--------------------OPT40600
      IF (NC.EQ.0) GO TO 150                                            OPT40610
      CALL FRTCMS ('CLRSCRN ')                                          OPT40620
120   WRITE (5,290)                                                     OPT40630
      CALL RDCHAR (IANS)                                                OPT40640
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 140                    OPT40650
130   WRITE (5,330)                                                     OPT40660
      GO TO 120                                                         OPT40670
140   CONTINUE                                                          OPT40680
      IF (IANS.EQ.IYES) ISAG=1                                          OPT40690
      IF (IANS.EQ.INO) ISAG=0                                           OPT40700
150   CONTINUE                                                          OPT40710
C-----------------------------------------------IGAM--------------------OPT40720
      IF (NG.EQ.0) GO TO 190                                            OPT40730
      CALL FRTCMS ('CLRSCRN ')                                          OPT40740
160   WRITE (5,300)                                                     OPT40750
      CALL RDCHAR (IANS)                                                OPT40760
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 180                    OPT40770
170   WRITE (5,330)                                                     OPT40780
      GO TO 160                                                         OPT40790
180   CONTINUE                                                          OPT40800
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      IF (IANS.EQ.IYES) IGAM=1                                          OPT40810
      IF (IANS.EQ.INO) IGAM=0                                           OPT40820
190   CONTINUE                                                          OPT40830
C-----------------------------------------------------ISAA-------------------OPT40840
      CALL FRTCMS ('CLRSCRN ')                                          OPT40850
200   WRITE (5,310)                                                     OPT40860
      CALL RDCHAR (IANS)                                                OPT40870
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 210                    OPT40880
      WRITE (5,330)                                                     OPT40890
      GO TO 200                                                         OPT40900
210   CONTINUE                                                          OPT40910
      IF (IANS.EQ.IYES) ISAA=1                                          OPT40920
      IF (IANS.EQ.INO) ISAA=0                                           OPT40930
C-----------------------------------------------------ISAB-------------------OPT40940
      CALL FRTCMS ('CLRSCRN ')                                          OPT40950
220   WRITE (5,320)                                                     OPT40960
      CALL RDCHAR (IANS)                                                OPT40970
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 230                    OPT40980
      WRITE (5,330)                                                     OPT40990
      GO TO 220                                                         OPT41000
230   CONTINUE                                                          OPT41010
      IF (IANS.EQ.IYES) ISAB=1                                          OPT41020
      IF (IANS.EQ.INO) ISAB=0                                           OPT41030
      RETURN                                                            OPT41040
C------------------------------------------------------------------------ OPT41050
240   FORMAT (I1,3X,I1)                                                 OPT41060
250   FORMAT (4I5)                                                      OPT41070
255   FORMAT (//////////////////////)                                   OPT41080
260   FORMAT (//,10X,46HTHE "F", "G", "H", "GAM", "A" AND "B" MATRICES, OPT41090
     1/,12X,42H FROM YOUR PREVIOUS OPTSYS RUN WERE SAVED.,//,10X,36HTHE OPT41100
     2FOLLOWING OPTIONS ARE AVAILABLE:,/15X,38H1. USE ALL OF THE SAME MAOPT41110
     3TRICES AGAIN.,/,15X,'2. USE SELECTED MATRICES AGAIN.',/,          OPT41120
     415X,'3. INPUT ALL NEW MATRICES.',//,10X,17HENTER 1, 2, OR 3.      OPT41130
     5,//,10X,'NOTE: EACH SAVED MATRIX WILL BE REDISPLAYED AT'          OPT41140
     6,/,10X,34HTHE PROPER INPUT SEQUENCE INTERVAL                      OPT41150
     7,/,10X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,10X,         OPT41160
     827HINDIVIDUAL MATRIX ELEMENTS.)                                   OPT41170
270    FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "F"-MATRIX FROM THE LASTOPT41180
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE MOPT41190
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41200
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41210
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)          OPT41220
280    FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "H"-MATRIX FROM THE LASTOPT41230
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE MOPT41240
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41250
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41260
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)          OPT41270
290    FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "G"-MATRIX FROM THE LASTOPT41280
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'        ,//,5X,39HNOTE: THE M
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INT
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HIND
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)
300   FORMAT (///,5X,52HDO YOU WISH TO SAVE THE "GAMMA"-MATRIX FROM THE
     1LAST,/,5X,  'RUN TO BE USED IN THIS RUN?'        ,//,5X,39HNOTE: T
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)
310   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "A"-MATRIX FROM THE LAST
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'        ,//,5X,39HNOTE: THE M
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INT
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HIND
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)
320   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "B"-MATRIX FROM THE LAST
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'        ,//,5X,39HNOTE: THE M
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INT
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HIND
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)
330   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY    ENTER "YES" OR "NO".)
      END
C======================================================================
C  SUBROUTINE RDMAT -- READS THE F, G, H, GAM, A AND B MATRICES FROM   =
C  MATRICES FROM THE DATA FILE OPTMAT ON FILEDEF 9.                    =
C======================================================================
      SUBROUTINE RDMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NO,NG,IRDMAT)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION BA(NS,NS),G(NS,NC),HO(NO,NS),GAM(NS,NG),FBGC(NC,NS),
     1AY(NO,NO),B(NC,NC),FBGE(NS,NO)
      IF(IRDMAT.EQ.0) RETURN
      REWIND 9
      READ (9,20) K,IANS
      READ (9,20) NSI,NCI,NOI,NGI
      READ(9,10)  ((BA(I,J),J=1,NSI),I=1,NSI)
      READ(9,10)  ((G(I,J),J=1,NCI),I=1,NSI)
      READ(9,10)  ((HO(I,J),J=1,NSI),I=1,NOI)
      READ(9,10)  ((GAM(I,J),J=1,NGI),I=1,NSI)
      READ(9,10)  ((FBGC(I,J),J=1,NSI),I=1,NCI)
      READ(9,10)  ((FBGE(I,J),J=1,NOI),I=1,NSI)
      READ(9,10)  ((AY(I,J),J=1,NOI),I=1,NOI)
      READ(9,10)  ((B(I,J),J=1,NCI),I=1,NCI)
      RETURN
C----------------------------------------------------------------------
10    FORMAT(4(D20.13))
20    FORMAT(4I5)
      END
C======================================================================
C  SUBROUTINE WRTMAT -- WRITES THE F, G, HO & GAM MATRICES TO          =
C  THE DATA FILE OPTMAT ON FILEDEF 9.                                    =OPT41770
C=======================================================================OPT41780
      SUBROUTINE WRTMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NO,NG)           OPT41790
      IMPLICIT REAL*8(A-H,O-Z)                                            OPT41800
      DIMENSION BA(NS,NS),G(NS,NC),HO(NO,NS),GAM(NS,NG),FBGC(NC,NS),      OPT41810
     1AY(NO,NO),B(NC,NC),FBGE(NS,NO)                                      OPT41820
C     INTEGER NS,NC,NO,NG,I,J,IANS,INO,IYES                               OPT41830
      DATA IYES/'Y'/,INO/'N'/                                             OPT41840
      WRITE (5,90)                                                        OPT41850
      CALL FRTCMS('CLRSCRN ')                                             OPT41860
10    WRITE(5,100)                                                        OPT41870
      CALL RDCHAR(IANS)                                                   OPT41880
      IF((IANS.EQ.INO).OR.(IANS.EQ.IYES)) GO TO 20                        OPT41890
      WRITE(5,110)                                                        OPT41900
      GO TO 10                                                            OPT41910
20    IF (IANS.EQ.INO) RETURN                                             OPT41920
      REWIND 9                                                            OPT41930
      I = 0                                                               OPT41940
      IANS = 1                                                            OPT41950
      WRITE(9,140) I,IANS                                                 OPT41960
      WRITE(9,120) NS,NC,NC,NG                                            OPT41970
      WRITE(9,130) ((BA(I,J),J=1,NS),I=1,NS)                              OPT41980
      WRITE(9,130) ((G(I,J),J=1,NC),I=1,NS)                               OPT41990
      WRITE(9,130) ((HO(I,J),J=1,NS),I=1,NO)                              OPT42000
      WRITE(9,130) ((GAM(I,J),J=1,NG),I=1,NS)                             OPT42010
      WRITE(9,130) ((FBGC(I,J),J=1,NS),I=1,NC)                            OPT42020
      WRITE(9,130) ((FBGE(I,J),J=1,NO),I=1,NS)                            OPT42030
      WRITE(9,130) ((AY(I,J),J=1,NO),I=1,NO)                              OPT42040
      WRITE(9,130) ((B(I,J),J=1,NC),I=1,NC)                               OPT42050
      STOP                                                                OPT42060
C---------------------------------------------------------------------- OPT42070
90    FORMAT(//////////////////////)                                      OPT42080
100   FORMAT(///,10X,'DO YOU WISH TO OBTAIN A TIME RESPONSE,',/,          OPT42090
     112X,'POLE-ZERO MAP, ROOT-LOCUS PLOT,  BODE PLOT,  NYQUIST',/,       OPT42100
     212X,'PLOT,  OR NICHOLS PLOT OF THE SYSTEM YOU ARE EVALUATING?',     OPT42110
     3/,24X,'(Y OR N)'                                                    OPT42120
     4///,5X,'NOTE: YOU MUST BE LOGGED ON AT A DUAL SCREEN',/,            OPT42130
     410X,'(TEK 618) TERMINAL TO UTILIZE THIS MODE.',///,10X,             OPT42140
     558HTHE F (SYSTEM), G (CONTROL), H (OBSERVABLES), GAM (NOISE),,/,    OPT42150
     613X,53HA (OUTPUT COST) AND B (CONTROL COST) MATRICES WILL BE,/,     OPT42160
     716X,'SAVED FOR REENTRY TO THE MAIN OPTSYS PROGRAM.')                OPT42170
110   FORMAT(10X,29HYOU MUST ANSWER (Y)ES OR (N)O   )                     OPT42180
120   FORMAT(4I5)                                                         OPT42190
130   FORMAT(4D20.13)                                                     OPT42200
140   FORMAT(I1,3X,I1)                                                    OPT42210
      END                                                                 OPT42220
```

APPENDIX C
OPTGRAPH PROGRAM LISTING

This portion of the thesis contains the OPTGRAPH FORTRAN program (54 pages).

```
C*******************************************************************************
C*******************************************************************************
C***********                                                         ***********
C**********                         OPTGRAPH                          **********
C********                     BY MICHAEL H.LAPTAS                       ********
C********                                                               ********
C********     THIS PROGRAM IS AN INTERACTIVE DISSPLA GRAPHICS           ********
C********     ROUNTINE USED TO PLOT POLE-ZERO, ROOT-LOCUS, BODE,        ********
C********     NYQUIST, AND NICHOLS PLOTS FROM THE OPTSYS PROGRAM        ********
C********     OPEN LOOP TRANSFER FUNCTIONS.                              *******
C********                                                                *******
C**********                        15 AUG 1984                        **********
C***********                                                         ***********
C*******************************************************************************
C*******************************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MA,MAG
      REAL*4 XDO,YDO,XNO,YNO,GOL
      COMPLEX*16 FTN,PLN,RTD,PLD,WN
      INTEGER I,J,LL,KK,NC,NS,NOB,IPZ,IRTLO,IBOD,II,JJ,LINES,LINE,K1,K2
     *,NN,IE,IA,IB
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)
      COMMON /SHEAD/ LINES(4,18),LINE(9)
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),
     *QR(500),OPSR(500),MAG(500)
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10
C-------------------------------------------------------------------------------
C   SUPPRESS POSSIBLE UNDERFLOW AND OVERFLOW ERROR MESSAGES-SUMMARY ONLY=
C-------------------------------------------------------------------------------
      CALL ERRSET (207,256,-1,1,1,209)
C--------------------ZERO VARIBLES---------------------------------------------
      NS = 0
      NC = 0
      NOB = 0
      DO 5 I = 1,2
      DO 5 J = 1,99
5     OLD(J,I) = 0.0
      DO 10 I = 1,12
      DO 10 J = 1,12
      DO 10 KK = 1,2
      DO 10 LL = 1,99
10    OLN(LL,KK,J,I) = 0.0
      DO 20 I = 1,12
      DO 20 J = 1,12
      DO 20 KK = 1,2
20    GAN(KK,J,I) = 0.0
C--------------------SELECT TRANSFER FUNCTION TYPE-----------------------------
```

```
30     CALL FRTCMS('CLRSCRN ')                                              OPT00490
       WRITE(6,900)                                                         OPT00500
       WRITE(6,750)                                                         OPT00510
35     WRITE(6,760)                                                         OPT00520
       CALL RDINT(IANS)                                                     OPT00530
       IF(IANS.GT.4.OR.IANS.LT.1) GO TO 34                                  OPT00540
       GO TO 36                                                             OPT00550
34     WRITE(6,509)                                                         OPT00560
       GO TO 35                                                             OPT00570
36     CONTINUE                                                             OPT00580
       IF(IANS.EQ.1) IFL = 10                                               OPT00590
       IF(IANS.EQ.2) IFL = 1                                                OPT00600
       IF(IANS.EQ.3) IFL = 4                                                OPT00610
       IF(IANS.EQ.4) GO TO 95                                               OPT00620
C------------------READ INPUT DISK-------------------------------------------OPT00630
       READ(IFL,100) IA,IB,NS,NC,NOB,IE,ITFX                                OPT00640
C------------------CHECK DATA FILE FOR PROPER DATA---------------------------OPT00650
       IF(IB.NE.0) GO TO 41                                                 OPT00660
       IF(ITFX.EQ.1) WRITE(6,510)                                           OPT00670
       IF(ITFX.EQ.2) WRITE(6,511)                                           OPT00680
       IF(ITFX.EQ.3) WRITE(6,512)                                           OPT00690
       GO TO 35                                                             OPT00700
41     IF(NS.NE.0) GO TO 42                                                 OPT00710
       WRITE(6,513)                                                         OPT00720
       GO TO 35                                                             OPT00730
42     IF(NC.NE.0) GO TO 43                                                 OPT00740
       IF(ITFX.EQ.1) WRITE(6,515)                                           OPT00750
       IF(ITFX.EQ.2) WRITE(6,517)                                           OPT00760
       IF(ITFX.EQ.3) WRITE(6,516)                                           OPT00770
       GO TO 35                                                             OPT00780
43     IF(NOB.NE.0) GO TO 44                                                OPT00790
       IF(ITFX.EQ.1) WRITE(6,516)                                           OPT00800
       IF(ITFX.EQ.2) WRITE(6,516)                                           OPT00810
       IF(ITFX.EQ.3) WRITE(6,515)                                           OPT00820
       GO TO 35                                                             OPT00830
C------------------MARKCV CRITERIA FOR DETERMINING EXTRANEOUS ZEROS---OPT00840
44     IF(IE.EQ.0) IE = 6                                                   OPT00850
       CC = 10.**(-IE)                                                      OPT00860
C------------------DENOMINATOR-----------------------------------------------OPT00870
       DO 50 I = 1,NS                                                       OPT00880
          READ(IFL,120) OLD(I,1),OLD(I,2)                                   OPT00890
50     CONTINUE                                                             OPT00900
C------------------NUMERATOR / GAIN / ORDER----------------------------------OPT00910
       NN = NOB*NC                                                          OPT00920
       DO 90 I = 1,NN                                                       OPT00930
       READ(IFL,101) KK,K2,K1                                               OPT00940
       READ(IFL,120) GAN(1,K2,K1),GAN(2,K2,K1)                              OPT00950
       IF(GAN(1,K2,K1).NE.0.0) GO TO 72                                     OPT00960
```

```
      DO 70 LL = 1,NS
      CLN(LL,1,K2,K1) = 0.0
      CLN(LL,2,K2,K1) = 0.0
70    CONTINUE
      GO TO 75
72    CONTINUE
      READ(IFL,130) K2,K1
      DO 75 LL = 1,NS
         READ(IFL,120) OLN(LL,1,K2,K1),OLN(LL,2,K2,K1)
75    CONTINUE
90    CONTINUE
      CALL GRAPH(NS,NC,NOB,IE,ITFX)
      GO TO 30
95    CALL DCNEPL
      STOP
C-----------------------------------------------------------------------
100   FORMAT(I1,I4,5I5)
101   FORMAT(5X,3I5)
120   FORMAT(5X,2D30.14)
130   FORMAT(5X,2I5)
509   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)
510   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'PROPER DATA FILE IS NOT AVAILABLE FOR OPEN LOOP TF ANALYSIS')
511   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'PROPER DATA FILE IS NOT AVAILABLE FOR NOISE TF ANALYSIS')
512   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'PROPER DATA FILE IS NOT AVAILABLE FOR CONPENSATOR TF ANALYSIS')
513   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'MUST INPUT "F" MATRIX IN OPTSYSX PROGRAM')
515   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'MUST INPUT "G" MATRIX IN OPTSYSX PROGRAM')
516   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'MUST INPUT "H" MATRIX IN OPTSYSX PROGRAM')
517   FORMAT(/,5X,'****** ERROR ******',/,10X,
     *'MUST INPUT "GAMMA" MATRIX IN OPTSYSX PROGRAM')
750   FORMAT(/,5X,'DO YOU DESIRE TO ANALYZE:',/,
     *10X,'1.  OPEN LOOP TRANSFER FUNCTION',/,
     *10X,'2.  NOISE TRANSFER FUNCTION',/,
     *10X,'3.  COMPENSATOR TRANSFER FUNCTION',/,
     *10X,'4.  EXIT OPTGRAPH')
760   FORMAT(5X,'ENTER OPTION NUMBER.')
900   FORMAT( //,20X,'OPTGRAPH',//)
C-----------------------------------------------------------------------
      END
C=======================================================================
C=======================================================================
      SUBROUTINE GRAPH (NS,NC,NOB,IE,ITFX)
C     CALLS GRAPHICS ROUTINES FOR POLE-ZERO PLOTS, ROOT LOCUS, AND
```

```
C      BODE PLOTS.
C=====================================================================
       IMPLICIT REAL*8(A-H,O-Z)
       INTEGER II,JJ,LL,KK,NC,NS,NOB,IANS,ITFX
C---------------------------------------------------------------------
       CALL FRTCMS ('CLRSCRN ')
       WRITE(6,900)
       IF(ITFX.EQ.1) WRITE(6,901)
       IF(ITFX.EQ.2) WRITE(6,902)
       IF(ITFX.EQ.3) WRITE(6,903)
       WRITE(6,904) NS,NC,NOB,IE
5      CONTINUE
C----------------------INPUT # AND OUTPUT #----------------------------
90     CALL FRTCMS ('CLRSCRN ')
       WRITE(6,900)
       WRITE (6,600)
10     WRITE (6,620)
       CALL RDINT (IANS)
       II= IANS
       IF(II.LT.1 .OR.II.GT.NC ) GO TO 15
       GO TO 20
15     WRITE(6,510) NC
       GO TO 10
20     WRITE (6,610)
       CALL RDINT (IANS)
       JJ= IANS
       IF(JJ.LT.1 .OR.JJ.GT.NOB) GO TO 25
       GO TO 100
25     WRITE(6,520) NOB
       GO TO 20
C---------------------OPTION SCREEN------------------------------------
100    CALL FRTCMS('CLRSCRN ')
       WRITE(6,900)
       IF(ITFX.EQ.1) WRITE(6,710)
       IF(ITFX.EQ.2) WRITE(6,711)
       IF(ITFX.EQ.3) WRITE(6,712)
       WRITE(6,720)II
       WRITE(6,730)JJ
       WRITE(6,750)
101    WRITE(6,760)
       CALL RDINT(IANS)
       IF(IANS.GT.7.OR.IANS.LT.1) GO TO 102
       GO TO 293
102    WRITE(6,509)
       GO TO 101
293    CONTINUE
       ICHG = 1
       GO TO (110,120,130,140,150,90,160),IANS
```

```
C----------------------POLE-ZERO-----------------------------------------OPTO1930
110   CALL PZERO(NS,JJ,II,ITFX)                                          OPTO1940
      GO TO 100                                                          OPTO1950
C----------------------ROOT LOCUS----------------------------------------OPTO1960
120   CALL RTLO(NS,JJ,II,ITFX)                                           OPTO1970
      GO TO 100                                                          OPTO1980
C----------------------BODE----------------------------------------------OPTO1990
130   CALL BCDE(NS,JJ,II,ITFX)                                           OPTO2000
      GO TO 100                                                          OPTO2010
C----------------------NYCUIST-------------------------------------------OPTO2020
140   CALL NYQST(NS,JJ,II,ITFX)                                          OPTO2030
      GO TO 100                                                          OPTO2040
C----------------------NICHOLS-------------------------------------------OPTO2050
150   CALL NICHOL(NS,JJ,II,ITFX)                                         OPTO2060
      GO TO 100                                                          OPTO2070
C----------------------EXIT OPGRAPH--------------------------------------OPTO2080
160   CONTINUE                                                           OPTO2090
      RETURN                                                             OPTO2100
C------------------------------------------------------------------------OPTO2110
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPRCPER DATA ENTRY   ', OPTO2120
     *3X,'ENTER "YES" OR "NO".',/)                                       OPTO2130
509   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)     OPTO2140
510   FORMAT (1X,'WARNING: THE TRANSFER FUNCTION INPUT# MUST NOT BE LESSOPTO2150
     * THAN 1 NOR GREATER THAN',I3,'  ')                                 OPTO2160
520   FORMAT (1X,'WARNING: THE TRANSFER FUNCTICN OUTPUT# MUST NCT BE LESOPTO2170
     *S THAN 1 NCR GREATER THAN',I3,'  ')                                OPTO2180
600   FORMAT (//,5X,'AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYCUIST,  OPTO2190
     *AND/OR NICHCLS',/,5X,'PLOT IS DESIRED FOR:',//)                    OPTO2200
610   FORMAT (10X,'OUTPUT # ?')                                          OPTO2210
620   FORMAT (10X,'INPUT # ?')                                           OPTO2220
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                        OPTO2230
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                            OPTO2240
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                      OPTO2250
720   FORMAT (10X,'INPUT #  =',I3)                                       OPTO2260
730   FORMAT (10X,'OUTPUT # =',I3)                                       OPTO2270
750   FORMAT(/,5X,'DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR DATA  OPTO2280
     * FOR:',/,                                                          OPTO2290
     *10X,'1.  PCLE-ZERO MAP',/,                                         OPTO2300
     *10X,'2.  RCCT-LOCUS',/,                                            OPTO2310
     *10X,'3.  BODE',/,                                                  OPTO2320
     *10X,'4.  NYCUIST (POLAR PLOT)',/,                                  OPTO2330
     *10X,'5.  NICHCLS',/,                                               OPTO2340
     *10X,'6.  ANCTHER INPUT/OUTPUT COMBINATION (SAME TRANSFER FUNCTION)OPTO2350
     *',/,                                                               OPTO2360
     *10X,'7.  ANCTHER TYPE TRANSFER FUNCTION /EXIT CPTGRAPH')           OPTO2370
760   FORMAT(5X,'ENTER OPTION NUMBER.')                                  OPTO2380
900   FORMAT( //,20X,'OPTGRAPH',//)                                      OPTO2390
901   FORMAT(5X,'THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM CPTSYS CONTOPTO2400
     *AINS:',/)                                                         OPT02410
902   FORMAT(5X,'THE NOISE TRANSFER SYSTEM OBTAINED FROM OPTSYS CONTAINSOPT02420
     *:',/)                                                             OPT02430
903   FORMAT(5X,'THE COMPENSATOR TRANSFER SYSTEM OBTAINED FROM OPTSYS COOPT02440
     *NTAINS:',/)                                                       OPT02450
904   FORMAT(10X,'1.  NUMBER OF STATES =                    ',I3,/,     OPT02460
     *10X,'2.  NUMBER OF CONTROLS (INPUTS) =       ',I3,/,              OPT02470
     *10X,'3.  NUMBER OF MEASUREMENTS (OUTPUTS) =',I3,/,                OPT02480
     *10X,'4.  MARKOV PARAMETER = 10.0**-',I2,//,                       OPT02490
     *15X,'CLEAR SCREEN TO CONTINUE',/////////////)                     OPT02500
C-----------------------------------------------------------------------OPT02510
      END                                                               OPT02520
C=======================================================================OPT02530
C=======================================================================OPT02540
      SUBROUTINE PZERO (NS,K2,K1,ITFX)                                  OPT02550
C     INTERACTIVELY PLOTS A POLE-ZERO PLOT USING DISSPLA GRAPHICS GIVEN OPT02560
C     THE ZERO AND POLE LOCATIONS                                       OPT02570
C=======================================================================OPT02580
      REAL*8 OLN,OLD,ORNUM,GAN,CO,ZERO                                  OPT02590
      REAL*4 XDO,YDO,XNO,YNO,XMIN,XMAX,YMIN,YMAX,XAXIS,YAXIS,PAGEX,     OPT02600
     *PAGEY,XX,YY,GOL,XL,YL,TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10    OPT02610
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,J1,ORD,LL,       OPT02620
     *IPT,IPP,IZR,ITFX                                                  OPT02630
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO          OPT02640
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                OPT02650
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT02660
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10           OPT02670
      DATA IY/'Y'/,IZ/'N'/                                              OPT02680
C--------------------GRAPHIC OR TABULAR OUTPUT--------------------------OPT02690
200   CALL FRTCMS('CLRSCRN ')                                           OPT02700
      WRITE(6,120)                                                      OPT02710
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT02720
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT02730
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT02740
      CALL PRTPLT(IPP)                                                  OPT02750
      GO TO (201,202,80),IPP                                            OPT02760
C--------------------INPUT ARRAYS----------------------------------------OPT02770
201   J1 = 0                                                            OPT02780
      DO 5 LL =1,NS                                                     OPT02790
      XNO(LL) = 0.0                                                     OPT02800
      YNO(LL) = 0.0                                                     OPT02810
      XDO(LL) = SNGL(OLD(LL,1))                                         OPT02820
      YDO(LL) = SNGL(OLD(LL,2))                                         OPT02830
      IF((DABS(OLN(LL,1,K2,K1)).LE.CO).AND.(DABS(OLN(LL,2,K2,K1)).LE.CO)OPT02840
     *) GO TO 6                                                         OPT02850
      J1= J1+1                                                          OPT02860
      XNO(J1) = SNGL(OLN(LL,1,K2,K1))                                   OPT02870
      YNO(J1) = SNGL(OLN(LL,2,K2,K1))                                   OPT02880
```

```
6     CONTINUE                                                          OPT02890
5     CONTINUE                                                          OPT02900
      ORD = DINT(GAN(1,K2,K1))                                          OPT02910
      IF(ORD.GT.J1) J1 = ORD                                            OPT02920
      GOL  = SNGL(GAN(2,K2,K1))                                         OPT02930
C-------------------------------------PLOT SETUP--------------------OPT02940
      ICHG = 0                                                          OPT02950
40    CALL FRTCMS('CLRSCRN ')                                           OPT02960
      IF(ICHG.EQ.1) GO TO 41                                            OPT02970
      WRITE (6,120)                                                     OPT02980
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT02990
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT03000
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT03010
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                     OPT03020
      IF(ICHG.EQ.1) GO TO 90                                            OPT03030
50    CALL FRTCMS('CLRSCRN ')                                           OPT03040
      CALL GGRAF(XMIN,XMAX,YMIN,YMAX)                                   OPT03050
      IF(ICHG.EQ.1) GO TO 90                                            OPT03060
60    CALL FRTCMS('CLRSCRN ')                                           OPT03070
      CALL GHEAD(NL)                                                    OPT03080
      IF(ICHG.EQ.1) GO TO 90                                            OPT03090
70    CONTINUE                                                          OPT03100
      IF(IPTR.EQ.2) GO TO 10                                            OPT03110
C-------------------------------------TEK 618-----------------------OPT03120
      CALL TEK618                                                       OPT03130
      CALL PAGE(PAGEX,PAGEY)                                            OPT03140
      CALL HWROT('AUTO')                                                OPT03150
      CALL HWSCAL('SCREEN')                                             OPT03160
      CALL NOBRDR                                                       OPT03170
      GO TO 20                                                          OPT03180
C-------------------------------------COMPRS------------------------OPT03190
10    CONTINUE                                                          OPT03200
      CALL COMPRS                                                       OPT03210
      CALL PAGE(PAGEX,PAGEY)                                            OPT03220
20    CONTINUE                                                          OPT03230
C-------------------------------------SCALING CONSTANTS-------------OPT03240
      CALL PSCALE(PAGEX)                                                OPT03250
C-------------------------------------PLOT EXECUTION----------------OPT03260
      CALL NOCHEK                                                       OPT03270
      CALL GRACE(0.)                                                    OPT03280
      CALL PHYSOR(T1,T1)                                                OPT03290
      XAXIS = PAGEX -2.*T1                                              OPT03300
      YAXIS = PAGEY -T1 -T2                                             OPT03310
      CALL AREA2D(XAXIS, YAXIS)                                         OPT03320
      CALL TRIPLX                                                       OPT03330
      CALL HEIGHT(TH)                                                   OPT03340
      CALL XNAME(' $',100)                                              OPT03350
      CALL HEIGHT(TH)                                                   OPT03360
      CALL YNAME(' $',100)                                                OPT03370
      CALL GRAF(XMIN,'SCALE',XMAX,YMIN,'SCALE',YMAX)                      OPT03380
      XL = (XMAX-XMIN)*0.1                                                OPT03390
      YL = (YMAX-YMIN)*0.1                                                OPT03400
      CALL RLVEC(XMAX+XL,0.0,XMIN-XL,0.0,0000)                            OPT03410
      CALL RLVEC(C.0,YMAX+YL,0.0,YMIN-YL,0000)                            OPT03420
C-----------------------------------HEADING-------------------------------OPT03430
      NN = NL + 1                                                         OPT03440
      IF(NL.EQ.0) GO TO 35                                                OPT03450
      DO 35 I=1,NL                                                        OPT03460
         CALL CLINE(I)                                                    OPT03470
         CALL HEADIN(LINE,100,T3,NN)                                      OPT03480
35    CONTINUE                                                            OPT03490
      IF(ITFX.EQ.1)                                                       OPT03500
     *   CALL HEADIN('OPEN LOOP TRANSFER POLE-ZERO MAP$',100,T3,NN)       OPT03510
      IF(ITFX.EQ.2)                                                       OPT03520
     *   CALL HEADIN('NOISE TRANSFER POLE-ZERO MAP$',100,T3,NN)           OPT03530
      IF(ITFX.EQ.3)                                                       OPT03540
     *   CALL HEADIN('COMPENSATOR TRANSFER POLE-ZERC MAP$',100,T3,NN)     OPT03550
C-----------------------------------POLE----------------------------------OPT03560
      CALL MARKER(4)                                                      OPT03570
      CALL SCLPIC(2.)                                                     OPT03580
      CALL CURVE(XDO,YDO,NS,-1)                                           OPT03590
C-----------------------------------ZERO----------------------------------OPT03600
      IF(J1.EQ.0) GO TO 36                                                OPT03610
      CALL MARKER(16)                                                     OPT03620
      CALL SCLPIC(2.)                                                     OPT03630
      CALL CURVE(XNO,YNO,J1,-1)                                           OPT03640
36    CONTINUE                                                            OPT03650
C-----------------------------------LEGEND--------------------------------OPT03660
      XX = XAXIS - T7                                                     OPT03670
      YY = YAXIS + T8                                                     OPT03680
      CALL HEIGHT(TH1)                                                    OPT03690
      CALL MESSAG('INPUT # =    $',100,XX+T8,YY+T10)                      OPT03700
      CALL HEIGHT(TH1)                                                    OPT03710
      CALL INTNO(K1,'ABUT','ABUT')                                        OPT03720
      CALL HEIGHT(TH1)                                                    OPT03730
      CALL MESSAG('OUTPUT # =   $',100,XX+T8,YY+T9)                       OPT03740
      CALL HEIGHT(TH1)                                                    OPT03750
      CALL INTNO(K2,'ABUT','ABUT')                                        OPT03760
      CALL HEIGHT(TH1)                                                    OPT03770
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                           OPT03780
      CALL HEIGHT(TH1)                                                    OPT03790
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                   OPT03800
      CALL BLREC(XX,YY,T5,T6,0.02)                                        OPT03810
C-------------------------------------------------------------------------OPT03820
C-----------------------------------GRID----------------------------------OPT03830
      CALL DOT                                                            OPT03840
      CALL GRID(1,1)                                                    OPT03850
      CALL RESET('DOT')                                                 OPT03860
      CALL ENDPL(0)                                                     OPT03870
      IF(IPTR.NE.2) GO TO 90                                            OPT03880
      CALL FRTCMS('CLRSCRN ')                                           OPT03890
      WRITE(6,130)                                                      OPT03900
C------------------------------------------CHANGES TO FLCT--------------OPT03910
90    CONTINUE                                                          OPT03920
      CALL FRTCMS('CLRSCRN ')                                           OPT03930
      WRITE(6,120)                                                      OPT03940
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT03950
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT03960
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT03970
      WRITE(6,100)                                                      OPT03980
30    WRITE(6,110)                                                      OPT03990
      CALL RDINT(IANS)                                                  OPT04000
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT04010
      GO TO 25                                                          OPT04020
15    WRITE(6,510)                                                      OPT04030
      GO TO 30                                                          OPT04040
25    CONTINUE                                                          OPT04050
      ICHG = 1                                                          OPT04060
      GO TO (40,50,60,70,200),IANS                                      OPT04070
C------------------------------------------TABULAR DATA-----------------OPT04080
202   CONTINUE                                                          OPT04090
      J1 = 0                                                            OPT04100
      ORD = DINT(GAN(1,K2,K1))                                          OPT04110
      ZERO =0.0                                                         OPT04120
      CALL FRTCMS('CLRSCRN ')                                           OPT04130
      WRITE(6,120)                                                      OPT04140
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT04150
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT04160
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT04170
      CALL PRTR(IFT)                                                    OPT04180
      CALL FRTCMS('CLRSCRN ')                                           OPT04190
      WRITE(IPT,120)                                                    OPT04200
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT04210
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT04220
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT04230
      WRITE(IPT,300) K1                                                 OPT04240
      WRITE(IPT,301) K2                                                 OPT04250
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT04260
      WRITE(IPT,311) NS                                                 OPT04270
      WRITE(IPT,360)                                                    OPT04280
      WRITE(IPT,340)                                                    OPT04290
      DO 210 I = 1,NS                                                   OPT04300
210   WRITE(IPT,330) OLD(I,1),OLD(I,2)                                  OPT04310
      IF(ORD.EQ.0) GO TO 230                                            OPT04320
      WRITE(IPT,310) ORD                                               OPTO4330
      WRITE(IPT,350)                                                   OPTO4340
      WRITE(IPT,340)                                                   OPTO4350
      DO 220 I = 1,NS                                                  OPTO4360
      IF((DABS(OLN(I,1,K2,K1)).LE.CO).AND.(DABS(OLN(I,2,K2,K1)).LE.CO) OPTO4370
     *) GO TO 220                                                      OPTO4380
      J1= J1+1                                                         OPTO4390
      WRITE(IPT,330) OLN(I,1,K2,K1),OLN(I,2,K2,K1)                     OPTO4400
  220 CONTINUE                                                         OPTO4410
      IZR = ORD - J1                                                   OPTO4420
      IF(IZR.LE.0) GO TO 240                                           OPTO4430
      DO 225 I = 1,IZR                                                 OPTO4440
  225 WRITE(IPT,330) ZERO, ZERO                                        OPTO4450
      GO TO 240                                                        OPTO4460
  230 WRITE(IPT,350)                                                   OPTO4470
      WRITE(IPT,360)                                                   OPTO4480
C----------------------------------------CHANGES FOR TABULAR DATA------OPTO4490
  240 IF(IPT.EQ.3) WRITE (6,401)                                       OPTO4500
      IF(IPT.EQ.2) WRITE (6,402)                                       OPTO4510
      WRITE(6,400)                                                     OPTO4520
      CALL RDCHAR (IANS)                                               OPTO4530
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                     OPTO4540
      GO TO 250                                                        OPTO4550
  245 WRITE (6,500)                                                    OPTO4560
      GO TO 240                                                        OPTO4570
  250 CONTINUE                                                         OPTO4580
      IF (IANS.EQ.IY) GO TO 202                                        OPTO4590
      IF (IANS.EQ.IZ) GO TO 200                                        OPTO4600
C----------------------------------------------------------------------OPTO4610
   80 RETURN                                                           OPTO4620
C----------------------------------------------------------------------OPTO4630
  100 FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPTO4640
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS',/,10X,'3.  HEADING',/OPTO4650
     *,10X,'4.  NO ADDITIONAL CHANGES - PLOT POLE-ZERO MAP',/,10X,'5.  NOPTO4660
     *O CHANGES - EXIT POLE-ZERO PLOTTING ROUTINE',/)                  OPTO4670
  110 FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                            OPTO4680
  120 FORMAT(//,15X,'POLE-ZERO MAP')                                   OPTO4690
  130 FORMAT(////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,     OPTO4700
     *15X,'CLEAR SCREEN TO CONTINUE',/////////////////////)            OPTO4710
  300 FORMAT(//,10X,'INPUT NUMBER =    ',I5)                           OPTO4720
  301 FORMAT(10X,'OUTPUT NUMBER =   ',I5)                              OPTO4730
  310 FORMAT(/,10X,'NUMERATOR ORDER =',I5)                             OPTO4740
  311 FORMAT(/,10X,'DENOMINATOR ORDER =',I5)                           OPTO4750
  320 FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)              OPTO4760
  330 FORMAT(10X,D12.4,5X,D12.4)                                       OPTO4770
  340 FORMAT(12X,'REAL PART',8X,'IMAGINARY PART',/)                    OPTO4780
  350 FORMAT(5X,'ZERO LOCATIONS')                                      OPTO4790
  360 FORMAT(5X,'POLE LOCATIONS')                                      OPTO4800
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380   FORMAT(/,15X,'NO REAL ZEROS',/)
400   FORMAT (/,5X,'DO YOU DESIRE TO CHANGE OUTPUT DEVICE?'
     *,/,10X,'TYPE "YES" OR "NO".',/)
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY    ',
     *3X,'ENTER "YES" OR "NO".',/)
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)
C------------------------------------------------------------------------
      END
C========================================================================
C========================================================================
      SUBROUTINE FTLO (NS,K2,K1,ITFX)
C     INTERACTIVELY PLOTS A ROOT-LOCUS PLOT USING DISSPLA GRAPHICS GIVEN
C     THE ZERO AND POLE LOCATIONS
C========================================================================
      REAL*8 OLD,CLN,MAG,QI,QR,QPSR,KMAX,KMIN,ZERO,GAIN,
     *DELTF,GAN,CC,XR,YI,CRNUM,K,KIC
      REAL*4 XDO,YDO,XNO,YNO,XMIN,XMAX,YMIN,YMAX,XAXIS,YAXIS,PAGEX,
     *PAGEY,XX,YY,GOL,XL,YL,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,TH1,T9,T10
      COMPLEX*16 FTN,PLN,RTD,PLD,CPOLN,WN,CPOLD,CPOL
      INTEGER NS,IPTR,II,JJ,NN,NL,LINES,IANS,ICHG,LINE,J1,ORD,ITFX,
     *I,L,N,N1,N2,K2,K1,NN1,NN2,ND1,ND2,J,LL,IER,PTS,IPT,IZR
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)
      COMMON /SHEAD/ LINES(4,18),LINE(9)
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),
     *QR(500),QPSR(500),MAG(500)
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10
      DATA IY/'Y'/,IZ/'N'/
C-------------------GRAPHIC OR TABULAR OUTPUT-----------------------------
200   CALL FRTCMS('CLRSCRN ')
      WRITE(6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
      CALL PRTPLT(IPP)
      GO TO (201,202,80),IPP
C----------------------------------------PLOT SETUP----------------------
201   CONTINUE
      ICHG = 0
40    CALL FRTCMS('CLRSCRN ')
      IF(ICHG.EQ.1) GO TO 41
      WRITE (6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
41    CALL GSETUP(IPTR,PAGEX,PAGEY)
      IF(ICHG.EQ.1) GO TO 90
50    CALL FRTCMS('CLRSCRN ')
      CALL GGRAF(XMIN,XMAX,YMIN,YMAX)
      IF(ICHG.EQ.1) GO TO 90
55    CALL FRTCMS('CLRSCRN ')
      CALL RANGK(KMIN,KMAX)
      IF(ICHG.EQ.1) GO TO 90
60    CALL FRTCMS('CLRSCRN ')
      CALL GHEAD(NL)
      IF(ICHG.EQ.1) GO TO 90
70    CONTINUE
      IF(IPTR.EQ.2) GO TO 10
C---------------------------------------TEK 618---------------------
      CALL TEK618
      CALL PAGE(PAGEX,PAGEY)
      CALL HWROT('AUTO')
      CALL HWSCAL('SCREEN')
      CALL NOBRDR
      GO TO 20
C---------------------------------------COMPRS----------------------
10    CONTINUE
      CALL COMPRS
      CALL PAGE(PAGEX,PAGEY)
20    CONTINUE
C---------------------------------------SCALING CONSTANTS-----------
      CALL PSCALE(PAGEX)
C---------------------------------------PLOT EXECUTION--------------
      CALL NOCHEK
      CALL GRACE(0.)
      CALL PHYSOR(T1,T1)
         XAXIS = PAGEX -2.0*T1
         YAXIS = PAGEY -T1 -T2
      CALL AREA2D(XAXIS, YAXIS)
      CALL TRIPLX
      CALL HEIGHT(TH)
      CALL XNAME(' $',100)
      CALL HEIGHT(TH)
      CALL YNAME(' $',100)
      CALL GRAF(XMIN,'SCALE',XMAX,YMIN,'SCALE',YMAX)
      XL = (XMAX-XMIN)*0.1
      YL = (YMAX-YMIN)*0.1
      CALL RLVEC(XMAX+XL,0.0,XMIN-XL,0.0,0000)
      CALL RLVEC(0.0,YMAX+YL,0.0,YMIN-YL,0000)
C---------------------------------------HEADING---------------------
      NN = NL + 1
      IF(NL.EQ.0) GO TO 35                                              OPT05770
      DO 35 I=1,NL                                                      OPT05780
         CALL CLINE(I)                                                  OPT05790
         CALL HEADIN(LINE,100,T3,NN)                                    OPT05800
35    CONTINUE                                                          OPT05810
      IF(ITFX.EQ.1)                                                     OPT05820
     *   CALL HEADIN('ROOT-LOCUS PLOT (OPEN LOOP TF)$',100,T3,NN)       OPT05830
      IF(ITFX.EQ.2)                                                     OPT05840
     *   CALL HEADIN('ROOT-LOCUS PLOT (NOISE TF)$',100,T3,NN)           OPT05850
      IF(ITFX.EQ.3)                                                     OPT05860
     *   CALL HEADIN('ROOT-LOCUS PLOT (COMPENSATOR TF)$',100,T3,NN)     OPT05870
C---------------------INPUT ARRAYS------------------------------------OPT05880
      ZERO = 0.0                                                        OPT05890
      J1 = 0                                                            OPT05900
      ND1 = NS + 1                                                      OPT05910
      ND2 = NS + 2                                                      OPT05920
      DO 5 LL =1,NS                                                     OPT05930
      XNO(LL) = 0.0                                                     OPT05940
      YNO(LL) = 0.0                                                     OPT05950
      QI(LL) = 0.0                                                      OPT05960
      QR(LL) = 0.0                                                      OPT05970
      XDO(LL) = SNGL(OLD(LL,1))                                         OPT05980
      YDO(LL) = SNGL(OLD(LL,2))                                         OPT05990
      RTD(LL) = CMPLX(OLD(LL,1),OLD(LL,2))                              OPT06000
      RTN(LL) = CMPLX(ZERO,ZERO)                                        OPT06010
      IF((DABS(OLN(LL,1,K2,K1)).LE.CO).AND.(DABS(OLN(LL,2,K2,K1)).LE.CO)OPT06020
     *) GO TO 6                                                         OPT06030
      J1= J1+1                                                          OPT06040
      XNO(J1) = SNGL(OLN(LL,1,K2,K1))                                   OPT06050
      YNO(J1) = SNGL(OLN(LL,2,K2,K1))                                   OPT06060
      RTN(J1) = CMPLX(OLN(LL,1,K2,K1),OLN(LL,2,K2,K1))                  OPT06070
6     CONTINUE                                                          OPT06080
5     CONTINUE                                                          OPT06090
      ORD = DINT(GAN(1,K2,K1))                                          OPT06100
      IF(ORD.GT.J1) J1 = ORD                                            OPT06110
      GOL  = SNGL(GAN(2,K2,K1))                                         OPT06120
      GAIN = GAN(2,K2,K1)                                               OPT06130
C-------------------------------------POLE----------------------------OPT06140
      CALL MARKER(4)                                                    OPT06150
      CALL SCLPIC(2.)                                                   OPT06160
      CALL CURVE(XDO,YDO,NS,-1)                                         OPT06170
C-------------------------------------ZERO----------------------------OPT06180
      IF(J1.EQ.0) GO TO 36                                              OPT06190
      CALL MARKER(16)                                                   OPT06200
      CALL SCLPIC(2.)                                                   OPT06210
      CALL CURVE(XNO,YNO,J1,-1)                                         OPT06220
36    CONTINUE                                                          OPT06230
C-------------------------------------POLYNOMIALS---------------------OPT06240
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C-----------------------------------------DENOMENATOR--------------------OPT06250
      CALL MAKPOL(NS,RTD,PLD)                                             OPT06260
      QI(1) = 1.C                                                         OPT06270
      DO 7 I = 2,ND1                                                      OPT06280
7     QI(I) = DREAL(PLD(ND2-I))                                           OPT06290
C-----------------------------------------NUMERATOR----------------------OPT06300
      IF(J1.EQ.0) GO TO 9                                                 OPT06310
      CALL MAKPOL(J1,RTN,PLN)                                             OPT06320
      JJ = NS - J1 + 2                                                    OPT06330
      QR(JJ-1) = 1.0                                                      OPT06340
      DO 8 I = JJ,ND1                                                     OPT06350
8     QR(I) = DREAL(PLN(ND2-I))                                           OPT06360
      GO TO 11                                                            OPT06370
9     QR(ND1) = 1.0                                                       OPT06380
      QR(1) = 0.C                                                         OPT06390
C-----------------------------------------ROOT FINDING ROUTINE-----------OPT06400
11    KIC = (KMAX-KMIN)/2000.                                             OPT06410
      K = KMIN                                                            OPT06420
      DO 52 J = 1,2000                                                    OPT06430
      DO 37 II = 1,ND1                                                    OPT06440
      MAG(II) = QI(II) + K*GAIN*QR(II)                                    OPT06450
37    CONTINUE                                                            OPT06460
      CALL ZRPOLY(MAG,NS,WN,IER)                                          OPT06470
      DO 51 II =1,NS                                                      OPT06480
      XR = DREAL(WN(II))                                                  OPT06490
      XNO(II) = SNGL(XR)                                                  OPT06500
      YI = DIMAG(WN(II))                                                  OPT06510
      YNO(II) = SNGL(YI)                                                  OPT06520
51    CONTINUE                                                            OPT06530
      CALL MARKER(4)                                                      OPT06540
      CALL SCLPIC(1.)                                                     OPT06550
      CALL CURVE(XNO,YNO,NS,-1)                                           OPT06560
      K=K+KIC                                                             OPT06570
52    CONTINUE                                                            OPT06580
C-----------------------------------------LEGEND-------------------------OPT06590
      XX = XAXIS - T7                                                     OPT06600
      YY = YAXIS + T8                                                     OPT06610
      CALL HEIGHT(TH1)                                                    OPT06620
      CALL MESSAG('INPUT # =    $',100,XX+T8,YY+T10)                      OPT06630
      CALL HEIGHT(TH1)                                                    OPT06640
      CALL INTNO(K1,'ABUT','ABUT')                                        OPT06650
      CALL HEIGHT(TH1)                                                    OPT06660
      CALL MESSAG('OUTPUT # =   $',100,XX+T8,YY+T9)                       OPT06670
      CALL HEIGHT(TH1)                                                    OPT06680
      CALL INTNO(K2,'ABUT','ABUT')                                        OPT06690
      CALL HEIGHT(TH1)                                                    OPT06700
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                           OPT06710
      CALL HEIGHT(TH1)                                                    OPT06720
      CALL REALNC(GOL,-3,'ABUT','ABUT')
      CALL BLREC(XX,YY,T5,T6,0.02)
C-------------------------------------------GRID------------------------
      CALL DOT
      CALL GRID(1,1)
      CALL RESET('DOT')
      CALL ENDPL(C)
      IF(IPTR.NE.2) GO TO 90
      CALL FRTCMS('CLRSCRN ')
      WRITE(6,13C)
C-------------------------------------------CHANGES TO PLOT-------------
9C    CCNTINUE
      CALL FRTCMS('CLRSCRN ')
      WRITE(6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
      WRITE(6,10C)
30    WRITE(6,110)
      CALL RCINT(IANS)
      IF(IANS.GT.6.OR.IANS.LT.1) GO TO 15
      GC TO 25
15    WRITE(6,510)
      GO TO 30
25    CCNTINUE
      ICHG = 1
      GO TO (40,5C,60,55,7C,200),IANS
C-------------------------------------------TABULAR DATA----------------
2C2   CCNTINUE
      ICHG =0
251   CALL FRTCMS('CLRSCRN ')
      IF(ICHG.EQ.1) GO TO 249
      WRITE(6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
249   CALL PRTR(IFT)
      IF(ICHG.EQ.1) GO TO 29C
252   CALL FRTCMS('CLRSCRN ')
      CALL RANGK(KMIN,KMAX)
      IF(ICHG.EQ.1) GO TO 290
253   CALL FRTCMS('CLRSCRN ')
      CALL NPTS(PTS)
      IF(ICHG.EQ.1) GO TO 290
C-------------------------------------------TABULATE DATA---------------
254   CONTINUE
      ZERO = 0.0
      J1 = 0
      ND1 = NS + 1
      ND2 = NS + 2
      ORD = DINT(GAN(1,K2,K1))
      GAIN = GAN(2,K2,K1)
      CALL FRTCMS('CLRSCRN ')
      WRITE(IPT,120)
      IF(ITFX.EQ.1) WRITE(IPT,710)
      IF(ITFX.EQ.2) WRITE(IPT,711)
      IF(ITFX.EQ.3) WRITE(IPT,712)
      WRITE(IPT,300) K1
      WRITE(IPT,301) K2
      WRITE(IPT,320) GAN(2,K2,K1)
      IF(ITFX.EQ.1) WRITE(IPT,121)
      IF(ITFX.EQ.2) WRITE(IPT,122)
      IF(ITFX.EQ.3) WRITE(IPT,123)
      WRITE(IPT,311) NS
      WRITE(IPT,360)
      WRITE(IPT,340)
      DO 210 I = 1,NS
210   WRITE(IPT,330) OLD(I,1),OLD(I,2)
      IF(ORD.EQ.0) GO TO 230
      WRITE(IPT,310) ORD
      WRITE(IPT,350)
      WRITE(IPT,340)
      DO 220 I = 1,NS
      RTD(I) = DCMPLX(OLD(I,1),OLD(I,2))
      RTN(I) = DCMPLX(ZERO,ZERO)
      IF((DABS(OLN(I,1,K2,K1)).LE.CO).AND.(DABS(OLN(I,2,K2,K1)).LE.CO)
     *) GO TO 220
      J1= J1+1
      RTN(J1) = DCMPLX(OLN(I,1,K2,K1),OLN(I,2,K2,K1))
      WRITE(IPT,330) OLN(I,1,K2,K1),OLN(I,2,K2,K1)
220   CONTINUE
      IZR = ORD - J1
      IF(IZR.LE.0) GO TO 240
      DO 225 I = 1,IZR
225   WRITE(IPT,330) ZERO, ZERO
      GO TO 240
230   WRITE(IPT,350)
      WRITE(IPT,380)
C-----------------------------------------POLYNOMIALS--------------------
C-----------------------------------------DENOMENATOR--------------------
240   CONTINUE
      CALL MAKPOL(NS,RTD,PLD)
      QI(1) = 1.0
      DO 207 I = 2,ND1
207   QI(I) = DREAL(PLD(ND2-I))
C-----------------------------------------NUMERATOR----------------------
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      IF(J1.EQ.0) GO TO 209                                             OPT07690
      CALL MAKPOL(J1,RTN,PLN)                                           OPT07700
      JJ = NS - J1 + 2                                                  OPT07710
      QR(JJ-1) = 1.0                                                    OPT07720
      DO 208 I = JJ,ND1                                                 OPT07730
208   QR(I) = DREAL(PLN(ND2-I))                                         OPT07740
      GO TO 211                                                         OPT07750
209   QR(ND1) = 1.0                                                     OPT07760
      QR(1) = 0.0                                                       OPT07770
C-----------------------------------------ROOT FINDING ROUTINE---------OPT07780
      WRITE(IPT,320)                                                    OPT07790
211   KIC = (KMAX-KMIN)/DFLOAT(PTS)                                     OPT07800
      K = KMIN                                                          OPT07810
      DO 262 J = 1,PTS                                                  OPT07820
      DO 237 II = 1,ND1                                                 OPT07830
      MAG(II) = CI(II) + K*GAIN*QR(II)                                  OPT07840
237   CONTINUE                                                          OPT07850
      CALL ZRPOLY(MAG,NS,WN,IER)                                        OPT07860
      WRITE(IPT,321) K                                                  OPT07870
      WRITE(IPT,340)                                                    OPT07880
      DO 261 II =1,NS                                                   OPT07890
      XR = DREAL(WN(II))                                                OPT07900
      YI = DIMAG(WN(II))                                                OPT07910
      WRITE(IPT,330) XR,YI                                              OPT07920
261   CONTINUE                                                          OPT07930
      K=K+KIC                                                           OPT07940
262   CONTINUE                                                          OPT07950
C-----------------------------------------CHANGES TABULAR DATA---------OPT07960
241   IF(IPT.EQ.3) WRITE (6,401)                                        OPT07970
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT07980
      WRITE(6,400)                                                      OPT07990
      CALL RDCHAR (IANS)                                                OPT08000
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT08010
      GO TO 250                                                         OPT08020
245   WRITE (6,500)                                                     OPT08030
      GO TO 241                                                         OPT08040
250   CONTINUE                                                          OPT08050
      IF (IANS.EQ.IY) GO TO 290                                         OPT08060
      IF (IANS.EQ.IZ) GO TO 200                                         OPT08070
C-----------------------------------------CHANGES ----------------------OPT08080
290   CONTINUE                                                          OPT08090
      CALL FRTCMS('CLRSCRN ')                                           OPT08100
      WRITE(6,120)                                                      OPT08110
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT08120
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT08130
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT08140
      WRITE(6,410)                                                      OPT08150
291   WRITE(6,110)                                                      OPT08160
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      CALL RCINT(IANS)                                                  OPTO8170
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPTO8180
      GO TO 293                                                         OPTO8190
292   WRITE(6,510)                                                      OPTO8200
      GO TO 291                                                         OPTO8210
293   CONTINUE                                                          OPTO8220
      ICHG = 1                                                          OPTO8230
      GO TO (251,252,253,254,200),IANS                                  OPTO8240
C-----------------------------------------------------------------------OPTO8250
80    RETURN                                                            OPTO8260
C-----------------------------------------------------------------------OPTO8270
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPTO8280
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS',/,10X,               OPTO8290
     *'3.  HEADING',/,10X,'4.  GAIN RANGE',/                            OPTO8300
     *,10X,'5.  NC ADDITICNAL CHANGES - PLOT ROOT-LCCUS',/,10X,         OPTO8310
     *'6.  NO CHANGES - EXIT ROOT-LCCUS PLOTTING RCUTINE',/)            OPTO8320
110   FORMAT(/,5X,'ENTER CPTION NUMBER.',/)                             OPTO8330
120   FORMAT(//,15X,'ROOT-LCCUS')                                       OPTO8340
121   FORMAT(/,5X,'OPEN LOCP TF POLES AND ZEROS')                       OPTO8350
122   FORMAT(/,5X,'NOISE TF POLES AND ZEROS')                           OPTO8360
123   FORMAT(/,5X,'COMPENSATOR TF POLES AND ZERCS')                     OPTO8370
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,     OPTO8380
     *15X,'CLEAR SCREEN TO CONTINUE',//////////////////////)            OPTO8390
300   FORMAT(//,10X,'INPUT NUMBER =    ',I5)                            OPTO8400
301   FORMAT(10X,'OUTPUT NUMBER =   ',I5)                               OPTO8410
310   FORMAT(/,10X,'NUMERATCR ORDER =',I5)                              OPTO8420
311   FORMAT(/,10X,'DENCMINATOR CRDER =',I5)                            OPTO8430
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)               OPTO8440
321   FORMAT(/,10X,'GAIN = ',D12.4)                                     OPTO8450
330   FORMAT(10X,D12.4,5X,D12.4)                                        OPTO8460
340   FORMAT(12X,'REAL PART',8X,'IMAGINARY PART',/)                     OPTO8470
350   FORMAT(10X,'ZERO LCCATICNS')                                      OPTO8480
360   FORMAT(10X,'POLE LOCATIONS')                                      OPTO8490
380   FORMAT(/,15X,'NO REAL ZEROS',/)                                   OPTO8500
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,             OPTO8510
     *10X,'TYPE "YES" OR "NO".',/)                                      OPTO8520
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                        OPTO8530
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                   OPTO8540
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,          OPTO8550
     *10X,'1.  OUTPUT DEVICE',/,                                        OPTO8560
     *10X,'2.  GAIN RANGE',/,                                           OPTO8570
     *10X,'3.  NUMBER OF PCINTS CALCULATED',/,                          OPTO8580
     *10X,'4.  NC ADDITIONAL CHANGES - TABULATE CATA',/,                OPTO8590
     *10X,'5.  EXIT ROOT-LCCUS TABULAR DATA ROUTINE',/)                 OPTO8600
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY    ', OPTO8610
     *3X,'ENTER "YES" OR "NO".',/)                                      OPTO8620
510   FORMAT(/,5X,'****** ERROR *****',10X,'IMPROPER DATA ENTRY',/)     OPTO8630
710   FORMAT (5X,'OPEN LCOP TRANSFER FUNCTION',/)                       OPTO8640
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711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                           OPT08650
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                     OPT08660
C-----------------------------------------------------------------------OPT08670
      END                                                               OPT08680
C=======================================================================OPT08690
C=======================================================================OPT08700
      SUBROUTINE BODE (NS,K2,K1,ITFX)                                   OPT08710
C     INTERATIVELY PLOTS A BODE PLOT USING DISSPLA GRAPHICS GIVEN       OPT08720
C     THE ZERO AND POLE LOCATIONS                                       OPT08730
C=======================================================================OPT08740
      REAL*8 OLN,CLD,ORNUM,MA,OMEGA,QI,QR,QPSR,MAG,GAN,CO               OPT08750
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,     OPT08760
     *PAGEY,XX,YY,PMIN,PMAX,MCYCLE,PCYCLE,FCYCLE,GOL,FL,FU,PM,GM,       OPT08770
     *TH,TH1,TS,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10                          OPT08780
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                     OPT08790
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,IPP,FTS,IPT    OPT08800
     *,ORD,ITFX                                                         OPT08810
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO          OPT08820
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                OPT08830
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT08840
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),   OPT08850
     *QR(500),QPSR(500),MAG(500)                                        OPT08860
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10           OPT08870
      DATA IY/'Y'/,IZ/'N'/                                              OPT08880
C-----------------------GRAPHIC OR TABULAR OUTPUT-----------------------OPT08890
200   CALL FRTCMS('CLRSCRN ')                                           OPT08900
      WRITE(6,120)                                                      OPT08910
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT08920
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT08930
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT08940
      CALL PRTPLT(IPP)                                                  OPT08950
      GO TO (201,202,80),IPP                                            OPT08960
C------------------------------------------PLOT SETUP-------------------OPT08970
201   CONTINUE                                                          OPT08980
      N = 500                                                           OPT08990
      ICHG = 0                                                          OPT09000
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT09010
40    CALL FRTCMS('CLRSCRN ')                                           OPT09020
      IF(ICHG.EQ.1) GO TO 41                                            OPT09030
      WRITE (6,120)                                                     OPT09040
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT09050
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT09060
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT09070
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                     OPT09080
      IF(ICHG.EQ.1) GO TO 90                                            OPT09090
50    CALL FRTCMS('CLRSCRN ')                                           OPT09100
      CALL FGRAF(FMIN,FMAX)                                             OPT09110
      IF(ICHG.EQ.1) GO TO 90                                            OPT09120
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60    CALL FRTCMS('CLRSCRN ')                                                   OPT09130
      CALL GHEAD(NL)                                                            OPT09140
      IF(ICHG.EQ.1) GO TO 90                                                    OPT09150
70    CONTINUE                                                                  OPT09160
C----------------------------------------SCALING CONSTANTS---------------------OPT09170
      CALL PSCALE(PAGEX)                                                        OPT09180
C------------------------------------------INPUT ARRAYS------------------------OPT09190
      GOL  = SNGL(GAN(2,K2,K1))                                                 OPT09200
      FL = FMIN*0.1                                                             OPT09210
      FU = FMAX*0.1                                                             OPT09220
      XAXIS = PAGEX -2.*T1                                                      OPT09230
      YAXIS = PAGEY -T1 -T2                                                     OPT09240
      FCYCLE = XAXIS/(ALOG10(FMAX)-ALOG10(FMIN))                                OPT09250
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                           OPT09260
      DO 5 I =1,N                                                               OPT09270
      OMEGA = DIMAG(WN(I))                                                      OPT09280
      XNO(I) = SNGL(OMEGA)                                                      OPT09290
      MA = 20.0*DLOG10(MAG(I))                                                  OPT09300
      YNO(I) = SNGL(MA)                                                         OPT09310
      YDO(I) = SNGL(QPSR(I))                                                    OPT09320
5     CONTINUE                                                                  OPT09330
      CALL MINMAX(N,YNO,MMIN,MMAX)                                              OPT09340
      MMIN = AINT(MMIN) - 1.0                                                   OPT09350
      MCYCLE = (MMAX-MMIN)/YAXIS                                                OPT09360
      MCYCLE = AINT(MCYCLE) + 1.0                                               OPT09370
      CALL MINMAX(N,YDO,PMIN,PMAX)                                              OPT09380
      PMIN = AINT(PMIN) - 1.0                                                   OPT09390
      PCYCLE = (PMAX-PMIN)/YAXIS                                                OPT09400
      PCYCLE = AINT(PCYCLE) + 1.0                                               OPT09410
C----------------------------------------MAGNITUDE PLOT------------------------OPT09420
C----------------------------------------TEK 618-------------------------------OPT09430
      IF(IPTR.EQ.2) GO TO 10                                                    OPT09440
      CALL TEK618                                                               OPT09450
      CALL PAGE(PAGEX,PAGEY)                                                    OPT09460
      CALL HWROT('AUTO')                                                        OPT09470
      CALL HWSCAL('SCREEN')                                                     OPT09480
      CALL NOBRDR                                                               OPT09490
      GO TO 20                                                                  OPT09500
C----------------------------------------COMPRS--------------------------------OPT09510
10    CONTINUE                                                                  OPT09520
      CALL COMPRS                                                               OPT09530
      CALL PAGE(PAGEX,PAGEY)                                                    OPT09540
20    CONTINUE                                                                  OPT09550
C------------------------------------------PLOT EXECUTION----------------------OPT09560
      CALL NOCHEK                                                               OPT09570
      CALL GRACE(0.)                                                            OPT09580
      CALL PHYSOR(T1,T1)                                                        OPT09590
      CALL AREA2D(XAXIS, YAXIS)                                                 OPT09600
      CALL TRIPLX                                                       OPT09610
      CALL HEIGHT(TH)                                                   OPT09620
      CALL XNAME('FREQUENCY - RADIANS PER SECOND $',100)                OPT09630
      CALL HEIGHT(TH)                                                   OPT09640
      CALL YNAME('MAGNITUDE - DECIBELS $',100)                          OPT09650
      CALL XLOG(FMIN,FCYCLE,MMIN,MCYCLE)                                OPT09660
      CALL BLVEC(FMAX+FU,0.0,FMIN-FL,0.0,0000)                          OPT09670
C--------------------------------------HEADING--------------------------OPT09680
      NN = NL + 1                                                       OPT09690
      IF(NL.EQ.0) GO TO 35                                              OPT09700
      DO 35 I=1,NL                                                      OPT09710
         CALL CLINE(I)                                                  OPT09720
         CALL HEADIN(LINE,100,T3,NN)                                    OPT09730
35    CONTINUE                                                          OPT09740
      IF(ITFX.EQ.1)                                                     OPT09750
     *   CALL HEADIN('OPEN LOOP TF BODE MAGNITUDE$',100,T3,NN)          OPT09760
      IF(ITFX.EQ.2)                                                     OPT09770
     *   CALL HEADIN('NOISE TF BODE MAGNITUDE$',100,T3,NN)              OPT09780
      IF(ITFX.EQ.3)                                                     OPT09790
     *   CALL HEADIN('COMPENSATOR TF BODE MAGNITUDE$',100,T3,NN)        OPT09800
C--------------------------------------MAGNITUDE------------------------OPT09810
      CALL CURVE(XNO,YNO,N,0)                                           OPT09820
C--------------------------------------LEGEND---------------------------OPT09830
      XX = XAXIS - T7                                                   OPT09840
      YY = YAXIS + T8                                                   OPT09850
      CALL HEIGHT(TH1)                                                  OPT09860
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                   OPT09870
      CALL HEIGHT(TH1)                                                  OPT09880
      CALL INTNO(K1,'ABUT','ABUT')                                      OPT09890
      CALL HEIGHT(TH1)                                                  OPT09900
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                    OPT09910
      CALL HEIGHT(TH1)                                                  OPT09920
      CALL INTNO(K2,'ABUT','ABUT')                                      OPT09930
      CALL HEIGHT(TH1)                                                  OPT09940
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                         OPT09950
      CALL HEIGHT(TH1)                                                  OPT09960
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                 OPT09970
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT09980
C--------------------------------------GRID-----------------------------OPT09990
      CALL DOT                                                          OPT10000
      CALL GRID(1,1)                                                    OPT10010
      CALL RESET('DOT')                                                 OPT10020
      CALL ENDPL(C)                                                     OPT10030
C--------------------------------------PHASE PLOT-----------------------OPT10040
C--------------------------------------TEK 618--------------------------OPT10050
      IF(IPTR.EQ.2) GO TO 11                                            OPT10060
      CALL TEK618                                                       OPT10070
      CALL PAGE(PAGEX,PAGEY)                                            OPT10080
      CALL HWROT('AUTO')                                                    OPT10090
      CALL HWSCAL('SCREEN')                                                 OPT10100
      CALL NOBRDR                                                           OPT10110
      GO TO 21                                                              OPT10120
C-----------------------------------------COMPRS-----------------------OPT10130
11    CONTINUE                                                              OPT10140
      CALL COMPRS                                                           OPT10150
      CALL PAGE(PAGEX,PAGEY)                                                OPT10160
21    CONTINUE                                                              OPT10170
C-----------------------------------------PLOT EXECUTION---------------OPT10180
      CALL NOCHEK                                                           OPT10190
      CALL GFACE(C.)                                                        OPT10200
      CALL PHYSOR(T1,T1)                                                    OPT10210
      CALL AREA2D(XAXIS, YAXIS)                                             OPT10220
      CALL TRIPLX                                                           OPT10230
      CALL HEIGHT(TH)                                                       OPT10240
      CALL XNAME('FREQUENCY - RADIANS PER SECOND $',100)                    OPT10250
      CALL HEIGHT(TH)                                                       OPT10260
      CALL YNAME('PHASE - DEGREES $',100)                                   OPT10270
      CALL XLOG(FMIN,FCYCLE,PMIN,PCYCLE)                                    OPT10280
      CALL RLVEC(FMAX+FU,180.0,FMIN-FL,180.0,0000)                          OPT10290
      CALL RLVEC(FMAX+FU,-180.0,FMIN-FL,-180.0,0000)                        OPT10300
C-----------------------------------------HEADING----------------------OPT10310
      NN = NL + 1                                                           OPT10320
      IF(NL.EQ.0) GO TO 36                                                  OPT10330
      DO 36 I=1,NL                                                          OPT10340
         CALL CLINE(I)                                                      OPT10350
         CALL HEADIN(LINE,100,T3,NN)                                        OPT10360
36    CONTINUE                                                              OPT10370
      IF(ITFX.EQ.1)                                                         OPT10380
     *   CALL HEADIN('OPEN LOOP TF BODE PHASE$',100,T3,NN)                  OPT10390
      IF(ITFX.EQ.2)                                                         OPT10400
     *   CALL HEADIN('NOISE TF BODE PHASE$',100,T3,NN)                      OPT10410
      IF(ITFX.EQ.3)                                                         OPT10420
     *   CALL HEADIN('COMPENSATOR TF BODE PHASE$',100,T3,NN)                OPT10430
C-----------------------------------------PHASE------------------------OPT10440
      CALL CURVE(XNC,YDO,N,0)                                               OPT10450
C-----------------------------------------LEGEND-----------------------OPT10460
      XX = XAXIS - T7                                                       OPT10470
      YY = YAXIS + T8                                                       OPT10480
      CALL HEIGHT(TH1)                                                      OPT10490
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                       OPT10500
      CALL HEIGHT(TH1)                                                      OPT10510
      CALL INTNO(K1,'ABUT','ABUT')                                          OPT10520
      CALL HEIGHT(TH1)                                                      OPT10530
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                        OPT10540
      CALL HEIGHT(TH1)                                                      OPT10550
      CALL INTNO(K2,'ABUT','ABUT')                                          OPT10560
      CALL HEIGHT(TH1)                                                  OPT10570
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                         OPT10580
      CALL HEIGHT(TH1)                                                  OPT10590
      CALL REALNC(GOL,-3,'ABUT','ABUT')                                 OPT10600
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT10610
C-------------------------------------GRID-----------------------------OPT10620
      CALL DOT                                                          OPT10630
      CALL GRID(1,1)                                                    OPT10640
      CALL RESET('DOT')                                                 OPT10650
      CALL ENDPL(0)                                                     OPT10660
      IF(IPTR.NE.2) GO TO 75                                            OPT10670
      CALL FRTCMS('CLRSCRN ')                                           OPT10680
      WRITE(6,130)                                                      OPT10690
C-------------------------------------GAIN AND PHASE MARGIN-----------OPT10700
75    CALL FRTCMS('CLRSCRN ')                                           OPT10710
      WRITE(6,135)                                                      OPT10720
C-------------------------------------GAIN MARGIN----------------------OPT10730
      DO 71 I = 2,N                                                     OPT10740
      IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72      OPT10750
      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72      OPT10760
      GO TO 71                                                          OPT10770
72    GM = 0.0 - YNO(I)                                                 OPT10780
      WRITE (6,140) XNO(I), GM                                          OPT10790
71    CONTINUE                                                          OPT10800
C-------------------------------------PHASE MARGIN---------------------OPT10810
      DO 76 I = 2,N                                                     OPT10820
      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                    OPT10830
      GO TO 76                                                          OPT10840
77    PM = 180.0 + YDO(I)                                               OPT10850
      WRITE (6,150) XNO(I), PM                                          OPT10860
76    CONTINUE                                                          OPT10870
      WRITE(6,160)                                                      OPT10880
C-------------------------------------CHANGES TO PLOT------------------OPT10890
50    CONTINUE                                                          OPT10900
      CALL FRTCMS('CLRSCRN ')                                           OPT10910
      WRITE(6,120)                                                      OPT10920
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT10930
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT10940
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT10950
      WRITE(6,100)                                                      OPT10960
30    WRITE(6,110)                                                      OPT10970
      CALL RDINT(IANS)                                                  OPT10980
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT10990
      GO TO 25                                                          OPT11000
15    WRITE(6,510)                                                      OPT11010
      GO TO 30                                                          OPT11020
25    CONTINUE                                                          OPT11030
      ICHG = 1                                                          OPT11040
      GO TO (40,50,60,70,200),IANS                                      OPT11050
C----------------------------------------TABULAR DATA-------------------OPT11060
202   CONTINUE                                                          OPT11070
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT11080
      ICHG =0                                                           OPT11090
251   CALL FRTCMS('CLRSCRN ')                                           OPT11100
      IF(ICHG.EQ.1) GO TO 249                                           OPT11110
      WRITE(6,120)                                                      OPT11120
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT11130
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT11140
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT11150
249   CALL PRTR(IPT)                                                    OPT11160
      IF(ICHG.EQ.1) GO TO 290                                           OPT11170
252   CALL FRTCMS('CLRSCRN ')                                           OPT11180
      CALL FGRAF(FMIN,FMAX)                                             OPT11190
      IF(ICHG.EQ.1) GO TO 290                                           OPT11200
253   CALL FRTCMS('CLRSCRN ')                                           OPT11210
      CALL NPTS(PTS)                                                    OPT11220
      IF(ICHG.EQ.1) GO TO 290                                           OPT11230
C---------------------------------------TABULATE DATA-------------------OPT11240
254   CONTINUE                                                          OPT11250
      ZERO = 0.0                                                        OPT11260
      J1 = 0                                                            OPT11270
      ORD = DINT(GAN(1,K2,K1))                                          OPT11280
      GAIN = GAN(2,K2,K1)                                               OPT11290
      CALL FRTCMS('CLRSCRN ')                                           OPT11300
      WRITE(IPT,120)                                                    OPT11310
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT11320
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT11330
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT11340
      WRITE(IPT,300) K1                                                 OPT11350
      WRITE(IPT,301) K2                                                 OPT11360
      WRITE(IPT,311) NS                                                 OPT11370
      WRITE(IPT,310) ORD                                                OPT11380
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT11390
      WRITE(IPT,350)                                                    OPT11400
      N = PTS                                                           OPT11410
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT11420
      DO 220 I = 1,N                                                    OPT11430
      OMEGA = DIMAG(WN(I))                                              OPT11440
      MA = 20.0*DLOG10(MAG(I))                                          OPT11450
      WRITE(IPT,330) OMEGA,MA,QPSR(I),QR(I),QI(I)                       OPT11460
220   CONTINUE                                                          OPT11470
C----------------------------------------CHANGES TABULAR DATA-----------OPT11480
240   IF(IPT.EQ.3) WRITE (6,401)                                        OPT11490
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT11500
      WRITE(6,400)                                                      OPT11510
      CALL RECHAR (IANS)                                                OPT11520
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245
      GO TO 250
245   WRITE (6,500)
      GO TO 240
250   CONTINUE
      IF (IANS.EQ.IY) GO TO 290
      IF (IANS.EQ.IZ) GO TO 200
C---------------------------------------------CHANGES ----------------------
290   CONTINUE
      CALL FRTCMS('CLRSCRN ')
      WRITE(6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
      WRITE(6,410)
291   WRITE(6,110)
      CALL RCINT(IANS)
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292
      GO TO 293
292   WRITE(6,510)
      GO TO 291
293   CONTINUE
      ICHG = 1
      GO TO (251,252,253,254,200),IANS
C---------------------------------------------------------------------------
80    RETURN
95    WRITE(6,520)
      RETURN
C---------------------------------------------------------------------------
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  P
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS (FREQUENCY RANGE)',
     */10X,'3.  HEADING',/
     *,10X,'4.  NO ADDITIONAL CHANGES - PLOT BODE PLOTS',/,10X,'5.  NO C
     *HANGES - EXIT BODE SUBROUTINE',/)
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)
120   FORMAT(//,15X,'BODE PLOT')
130   FORMAT(////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,
     *15X,'CLEAR SCREEN TO CONTINUE',///////////////////////)
135   FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)
140   FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC;'1X,
     *'GAIN MARGIN IS ',F10.4,' DB')
150   FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC;',1X,
     *,'PHASE MARGIN IS',F10.4,' DEG')
160   FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',//////////////////////////)
300   FORMAT(//,10X,'INPUT NUMBER =       ',I5)
301   FORMAT(10X,'OUTPUT NUMBER =    ',I5)
310   FORMAT(10X,'NUMERATOR ORDER =  ',I5)
311   FORMAT(10X,'DENOMINATOR ORDER =',I5)
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320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)                 OPT12010
330   FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)                OPT12020
350   FORMAT(5X,'  FREQUENCY ',3X,'  MAGNITUDE ',3X,' PHASE      ',       OPT12030
     * 3X,'     REAL    ',3X,'   IMAGINARY',                              OPT12040
     */,5X,'  (RAD/SEC) ',3X,'  (DECIBELS)',3X,' (DEGREES)',              OPT12050
     * 3X,'     PART    ',3X,'    PART     ')                             OPT12060
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,               OPT12070
     *10X,'TYPE "YES" OR "NO".',/)                                        OPT12080
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                          OPT12090
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                     OPT12100
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,            OPT12110
     *10X,'1.  OUTPUT DEVICE',/,                                          OPT12120
     *10X,'2.  FREQUENCY RANGE',/,                                        OPT12130
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,                            OPT12140
     *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,                  OPT12150
     *10X,'5.  EXIT BODE TABULAR DATA ROUTINE',/)                         OPT12160
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT12170
     *3X,'ENTER "YES" OR "NO".',/)                                        OPT12180
501   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT12190
     *3X,'ENTER "YES" TO CONTINUE',/)                                     OPT12200
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)      OPT12210
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TO ZEROPT12220
     *O',/)                                                               OPT12230
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                         OPT12240
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                             OPT12250
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                       OPT12260
C-----------------------------------------------------------------------OPT12270
      END                                                                 OPT12280
C=======================================================================OPT12290
C=======================================================================OPT12300
      SUBROUTINE NYQST (NS,K2,K1,ITFX)                                    OPT12310
C     INTERATIVELY PLOTS A NYQUIST PLOT USING DISSPLA GRAPHICS GIVEN      OPT12320
C     THE ZERO AND POLE LOCATIONS                                         OPT12330
C=======================================================================OPT12340
      REAL*8 OLN,OLD,ORNUM,OI,QR,QPSR,MAG,GAN,CO,MA,OMEGA                 OPT12350
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,       OPT12360
     *PAGEY,XX,YY,GOL,FL,FU,PM,GM,C2,C3,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,    OPT12370
     *QRMIN,QRMAX,QIMIN,QIMAX,RL,B1,B2,B3,RSTEP,THEFAC,TH1,T9,T10         OPT12380
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                       OPT12390
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,CRD,IPP,PTS,IPTOPT12400
     *,KK,J,II,N1,ITFX                                                    OPT12410
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CC            OPT12420
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                  OPT12430
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                  OPT12440
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),OI(500),     OPT12450
     *QR(500),QPSR(500),MAG(500)                                          OPT12460
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10             OPT12470
      DATA IY/'Y'/,IZ/'N'/                                                OPT12480
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C-----------------------GRAPHIC OR TABULAR OUTPUT----------------------OPT12490
200    CALL FRTCMS('CLRSCRN ')                                          OPT12500
       WRITE(6,120)                                                     OPT12510
       IF(ITFX.EQ.1) WRITE(6,710)                                       OPT12520
       IF(ITFX.EQ.2) WRITE(6,711)                                       OPT12530
       IF(ITFX.EQ.3) WRITE(6,712)                                       OPT12540
       CALL PRTPLT(IPP)                                                 OPT12550
       GO TO (201,202,80),IPP                                           OPT12560
C--------------------------------------PLOT SETUP-----------------------OPT12570
201    CONTINUE                                                         OPT12580
       N = 500                                                          OPT12590
       ICHG = 0                                                         OPT12600
       IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                 OPT12610
40     CALL FRTCMS('CLRSCRN ')                                          OPT12620
       IF(ICHG.EQ.1) GO TO 41                                           OPT12630
       WRITE (6,120)                                                    OPT12640
       IF(ITFX.EQ.1) WRITE(6,710)                                       OPT12650
       IF(ITFX.EQ.2) WRITE(6,711)                                       OPT12660
       IF(ITFX.EQ.3) WRITE(6,712)                                       OPT12670
41     CALL GSETUP(IPTR,PAGEX,PAGEY)                                    OPT12680
       IF(ICHG.EQ.1) GO TO 90                                           OPT12690
50     CALL FRTCMS('CLRSCRN ')                                          OPT12700
       CALL FGRAF(FMIN,FMAX)                                            OPT12710
       IF(ICHG.EQ.1) GO TO 90                                           OPT12720
60     CALL FRTCMS('CLRSCRN ')                                          OPT12730
       CALL GHEAD(NL)                                                   OPT12740
       IF(ICHG.EQ.1) GO TO 90                                           OPT12750
70     CONTINUE                                                         OPT12760
C--------------------------------------SCALING CONSTANTS----------------OPT12770
       CALL PSCALE(PAGEX)                                               OPT12780
C----------------------------------------INPUT ARRAYS-------------------OPT12790
       GOL  = SNGL(GAN(2,K2,K1))                                        OPT12800
       CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                  OPT12810
       DO 5 I =1,N                                                      OPT12820
       XNO(I) = SNGL(QR(I))                                             OPT12830
       YNO(I) = SNGL(QI(I))                                             OPT12840
5      CONTINUE                                                         OPT12850
       CALL MINMAX(N,XNO,QRMIN,QRMAX)                                   OPT12860
       CALL MINMAX(N,YNO,QIMIN,QIMAX)                                   OPT12870
C--------------------------------------PLOT LIMITS----------------------OPT12880
       XAXIS = PAGEX -2.*T1                                             OPT12890
       YAXIS = PAGEY -T1 -T2                                            OPT12900
       IF(QRMIN.GT.-1.) QRMIN = -1.0                                    OPT12910
       IF(QRMAX.LT.0.0) QRMAX = 0.0                                     OPT12920
       IF(QIMIN.GT.0.0) QIMIN = 0.0                                     OPT12930
       IF(QIMAX.LT.0.0) QIMAX = 0.0                                     OPT12940
       IF((QRMAX-QRMIN).GE.(QIMAX-QIMIN)) GO TO 6                       OPT12950
       RL = QIMAX - QIMIN                                               OPT12960
```

```
      GO TO 7                                                           OPT12970
6     RL = QRMAX - QRMIN                                                OPT12980
7     B1 = .2*XAXIS                                                     OPT12990
      B2 = .5*XAXIS                                                     OPT13000
      B3 = XAXIS                                                        OPT13010
      C2 = .5*YAXIS                                                     OPT13020
      C3 = YAXIS                                                        OPT13030
      KK = 1                                                            OPT13040
      IF(RL.GT.B1) KK=2                                                 OPT13050
      IF(RL.GT.B2) KK=3                                                 OPT13060
      IF(RL.GT.B3) KK=4                                                 OPT13070
      GO TO (11,12,13,14),KK                                            OPT13080
11    RL = B1                                                           OPT13090
      GO TO 16                                                          OPT13100
12    RL = B2                                                           OPT13110
      GO TO 16                                                          OPT13120
13    RL = B3                                                           OPT13130
      GO TO 16                                                          OPT13140
14    II = IFIX(RL)                                                     OPT13150
      N1 = IFIX(B2)                                                     OPT13160
17    J = MOD(II,N1)                                                    OPT13170
      IF(J.EQ.0) GO TO 21                                               OPT13180
      II = II+1                                                         OPT13190
      GO TO 17                                                          OPT13200
21    RSTEP = (FLOAT(II))/(FLOAT(N1))                                   OPT13210
      GO TO 18                                                          OPT13220
16    RSTEP = RL/B3                                                     OPT13230
18    IF(((QRMAX-QRMIN)/RSTEP).GE.B2) GO TO 22                          OPT13240
      XDIST = B2                                                        OPT13250
      GO TO 23                                                          OPT13260
22    XDIST = -QRMIN/RSTEP                                              OPT13270
23    IF(((QIMAX-QIMIN)/RSTEP).GE.C2) GO TO 24                          OPT13280
      YDIST = C2                                                        OPT13290
      GO TO 26                                                          OPT13300
24    YDIST = -QIMIN/RSTEP                                              OPT13310
26    IF(XDIST.GT.B3) XDIST = B3                                        OPT13320
      IF(YDIST.GT.C3) YDIST = C3                                        OPT13330
      THEFAC = 3.1415927/180.                                           OPT13340
C-------------------------------------TEK 618---------------------------OPT13350
      IF(IPTR.EQ.2) GO TO 10                                            OPT13360
      CALL TEK618                                                       OPT13370
      CALL PAGE(PAGEX,PAGEY)                                            OPT13380
      CALL HWROT('AUTO')                                                OPT13390
      CALL HWSCAL('SCREEN')                                             OPT13400
      CALL NOBRDR                                                       OPT13410
      GO TO 20                                                          OPT13420
C-------------------------------------COMPRS----------------------------OPT13430
10    CONTINUE                                                          OPT13440
```

```
      CALL COMPRS                                                       OPT13450
      CALL PAGE(PAGEX,PAGEY)                                            OPT13460
20    CONTINUE                                                          OPT13470
C-------------------------------------PLOT EXECUTION--------------------OPT13480
      CALL NOCHEK                                                       OPT13490
      CALL GRACE(0.)                                                    OPT13500
      CALL PHYSOR(T1,T1)                                                OPT13510
      CALL AREA2D(XAXIS, YAXIS)                                         OPT13520
      CALL TRIPLX                                                       OPT13530
      CALL HEIGHT(TH)                                                   OPT13540
      CALL XNAME(' $',100)                                              OPT13550
      CALL HEIGHT(TH)                                                   OPT13560
      CALL YNAME(' $',100)                                              OPT13570
C------------------------------------POLAR PLOT-------------------------OPT13580
      CALL POLAR(THEFAC,RSTEP,XDIST,YDIST)                              OPT13590
C------------------------------------HEADING----------------------------OPT13600
      NN = NL + 1                                                       OPT13610
      IF(NL.EQ.0) GO TO 35                                              OPT13620
      DO 35 I=1,NL                                                      OPT13630
         CALL CLINE(I)                                                  OPT13640
         CALL HEADIN(LINE,100,T3,NN)                                    OPT13650
35    CONTINUE                                                          OPT13660
      IF(ITFX.EQ.1)                                                     OPT13670
     *   CALL HEADIN('OPEN LOOP TRANSFER NYQUIST$',100,T3,NN)           OPT13680
      IF(ITFX.EQ.2)                                                     OPT13690
     *   CALL HEADIN('NOISE TRANSFER NYQUIST$',100,T3,NN)               OPT13700
      IF(ITFX.EQ.3)                                                     OPT13710
     *   CALL HEADIN('COMPENSATOR TRANSFER NYQUIST$',100,T3,NN)         OPT13720
C------------------------------------AXIS PLOT--------------------------OPT13730
      XDO(1) = 0.0                                                      OPT13740
      XDO(2) = RL*2.0                                                   OPT13750
      YDO(1) = 0.0                                                      OPT13760
      YDO(2) = 0.0                                                      OPT13770
      DO 27 I = 1,4                                                     OPT13780
      CALL CURVE(YDO,XDO,2,0)                                           OPT13790
      YDO(1) = YDO(1) + 90.                                             OPT13800
27    CONTINUE                                                          OPT13810
C------------------------------------UNIT CIRCLE------------------------OPT13820
      CALL DOT                                                          OPT13830
      CALL GRID(1,1)                                                    OPT13840
      XDO(1) = 0.0                                                      OPT13850
      YDO(1) = 1.0                                                      OPT13860
      DO 28 I = 2,360                                                   OPT13870
      XDO(I) = XDO(I-1) + 1.0                                           OPT13880
      YDO(I) = 1.0                                                      OPT13890
28    CONTINUE                                                          OPT13900
      CALL CURVE(XDO,YDO,360,0)                                         OPT13910
      CALL RESET('DOT')                                                 OPT13920
```

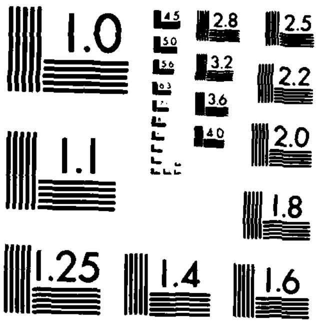
```
C-----------------------------------------CURVE PLCT--------------------OPT13930
      DO 29 I = 1,N                                                     OPT13940
      XNO(I) = SNGL(QPSR(I))                                            OPT13950
      YNO(I) = SNGL(MAG(I))                                             OPT13960
29    CONTINUE                                                          OPT13970
      CALL CURVE(XNO,YNO,N,0)                                           OPT13980
      CALL FRAME                                                        OPT13990
C-----------------------------------------LEGEND------------------------OPT14000
      XX = XAXIS - T7                                                   OPT14010
      YY = YAXIS + T8                                                   OPT14020
      CALL HEIGHT(TH1)                                                  OPT14030
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                   OPT14040
      CALL HEIGHT(TH1)                                                  OPT14050
      CALL INTNO(K1,'ABUT','ABUT')                                      OPT14060
      CALL HEIGHT(TH1)                                                  OPT14070
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                    OPT14080
      CALL HEIGHT(TH1)                                                  OPT14090
      CALL INTNO(K2,'ABUT','ABUT')                                      OPT14100
      CALL HEIGHT(TH1)                                                  OPT14110
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                         OPT14120
      CALL HEIGHT(TH1)                                                  OPT14130
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                 OPT14140
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT14150
C-----------------------------------------------------------------------OPT14160
      CALL ENDPL(0)                                                     OPT14170
      IF(IPTR.NE.2) GO TO 75                                            OPT14180
      CALL FRTCMS('CLRSCRN ')                                           OPT14190
      WRITE(6,130)                                                      OPT14200
C-----------------------------------------GAIN AND PHASE MARGIN---------OPT14210
75    DO 73 I =1,N                                                      OPT14220
      OMEGA = DIMAG(WN(I))                                              OPT14230
      XNO(I) = SNGL(OMEGA)                                              OPT14240
      MA = 20.0*DLOG10(MAG(I))                                          OPT14250
      YNO(I) = SNGL(MA)                                                 OPT14260
      YDO(I) = SNGL(QPSR(I))                                            OPT14270
73    CONTINUE                                                          OPT14280
      CALL FRTCMS('CLRSCRN ')                                           OPT14290
      WRITE(6,135)                                                      OPT14300
C-----------------------------------------GAIN MARGIN-------------------OPT14310
      DO 71 I = 2,N                                                     OPT14320
      IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72      OPT14330
      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72      OPT14340
      GO TO 71                                                          OPT14350
72    GM = 0.0 - YNO(I)                                                 OPT14360
      WRITE (6,140) XNO(I), GM                                          OPT14370
71    CONTINUE                                                          OPT14380
C-----------------------------------------PHASE MARGIN------------------OPT14390
      DO 76 I = 2,N                                                     OPT14400
      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                    OPT14410
      GO TO 76                                                          OPT14420
77    PM = 180.0 + YDO(I)                                               OPT14430
      WRITE (6,150) XNO(I), PM                                          OPT14440
76    CONTINUE                                                          OPT14450
      WRITE(6,160)                                                      OPT14460
C-----------------------------------CHANGES TO PLOT----------------------OPT14470
90    CONTINUE                                                          OPT14480
      CALL FRTCMS('CLRSCRN ')                                           OPT14490
      WRITE(6,120)                                                      OPT14500
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT14510
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT14520
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT14530
      WRITE(6,100)                                                      OPT14540
30    WRITE(6,110)                                                      OPT14550
      CALL RDINT(IANS)                                                  OPT14560
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT14570
      GO TO 25                                                          OPT14580
15    WRITE(6,510)                                                      OPT14590
      GO TO 30                                                          OPT14600
25    CONTINUE                                                          OPT14610
      ICHG = 1                                                          OPT14620
      GO TO (40,50,60,70,200),IANS                                      OPT14630
C-----------------------------------TABULAR DATA-------------------------OPT14640
202   CONTINUE                                                          OPT14650
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT14660
      ICHG =0                                                           OPT14670
251   CALL FRTCMS('CLRSCRN ')                                           OPT14680
      IF(ICHG.EQ.1) GO TO 249                                           OPT14690
      WRITE(6,120)                                                      OPT14700
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT14710
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT14720
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT14730
249   CALL PRTR(IPT)                                                    OPT14740
      IF(ICHG.EQ.1) GO TO 290                                           OPT14750
252   CALL FRTCMS('CLRSCRN ')                                           OPT14760
      CALL FGRAF(FMIN,FMAX)                                             OPT14770
      IF(ICHG.EQ.1) GO TO 290                                           OPT14780
253   CALL FRTCMS('CLRSCRN ')                                           OPT14790
      CALL NPTS(PTS)                                                    OPT14800
      IF(ICHG.EQ.1) GO TO 290                                           OPT14810
C-----------------------------------TABULATE DATA------------------------OPT14820
254   CONTINUE                                                          OPT14830
      ZERO = 0.0                                                        OPT14840
      J1 = 0                                                            OPT14850
      CRD = DINT(GAN(1,K2,K1))                                          OPT14860
      GAIN = GAN(2,K2,K1)                                               OPT14870
      CALL FRTCMS('CLRSCRN ')                                           OPT14880
```

AD-A152 148 DEVELOPMENT OF GRAPHICAL POLE-ZERO ROOT-LOCUS BODE 3/3
NYQUIST AND NICHOLS RESPONSES USING THE OPTSYSX PROGRAM
(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA M H LAPTAS
UNCLASSIFIED SEP 84 F/G 9/2 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A

```
      WRITE(IPT,120)                                                    OPT14890
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT14900
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT14910
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT14920
      WRITE(IPT,300) K1                                                 OPT14930
      WRITE(IPT,301) K2                                                 OPT14940
      WRITE(IPT,311) NS                                                 OPT14950
      WRITE(IPT,310) CRD                                                OPT14960
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT14970
      WRITE(IPT,350)                                                    OPT14980
      N = PTS                                                           OPT14990
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT15000
      DO 220 I = 1,N                                                    OPT15010
      OMEGA = DIMAG(WN(I))                                              OPT15020
      WRITE(IPT,330) OMEGA,MAG(I),QPSR(I),QR(I),CI(I)                   OPT15030
220   CONTINUE                                                          OPT15040
C----------------------------------------CHANGES TABULAR DATA----------OPT15050
240   IF(IPT.EQ.3) WRITE (6,401)                                        OPT15060
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT15070
      WRITE(6,400)                                                      OPT15080
      CALL RDCHAR (IANS)                                                OPT15090
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT15100
      GO TO 250                                                         OPT15110
245   WRITE (6,500)                                                     OPT15120
      GO TO 240                                                         OPT15130
250   CONTINUE                                                          OPT15140
      IF (IANS.EQ.IY) GO TO 290                                         OPT15150
      IF (IANS.EQ.IZ) GO TO 200                                         OPT15160
C----------------------------------------CHANGES ----------------------OPT15170
290   CONTINUE                                                          OPT15180
      CALL FRTCMS('CLRSCRN ')                                           OPT15190
      WRITE(6,120)                                                      OPT15200
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT15210
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT15220
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT15230
      WRITE(6,410)                                                      OPT15240
291   WRITE(6,110)                                                      OPT15250
      CALL RDINT(IANS)                                                  OPT15260
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT15270
      GO TO 293                                                         OPT15280
292   WRITE(6,510)                                                      OPT15290
      GO TO 291                                                         OPT15300
293   CONTINUE                                                          OPT15310
      ICHG = 1                                                          OPT15320
      GO TO (251,252,253,254,200),IANS                                  OPT15330
C---------------------------------------------------------------------OPT15340
80    RETURN                                                            OPT15350
95    WRITE(6,520)                                                      OPT15360
```

```
      RETURN
C-----------------------------------------------------------------------
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  P
     *LOTTER / PAGE SIZE',/,10X,'2.  FREQUENCY RANGE',/,10X,'3.  HEADING
     *',/,10X,'4.  NO ADDITIONAL CHANGES - PLOT NYQUIST PLOTS',/,10X,
     *'5.  NO CHANGES - EXIT NYQUIST PLOTTING ROUTINE',/)
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)
120   FORMAT(//,15X,'NYQUIST PLOT')
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,
     *15X,'CLEAR SCREEN TO CONTINUE',/////////////////////)
135   FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)
140   FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC;'1X,
     *'GAIN MARGIN IS ',F10.4,' DB')
150   FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC;',1X,
     *,'PHASE MARGIN IS',F10.4,' DEG')
160   FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',//////////////////////)
300   FORMAT(//,10X,'INPUT NUMBER =        ',I5)
301   FORMAT(10X,'OUTPUT NUMBER =      ',I5)
310   FORMAT(10X,'NUMERATOR ORDER =   ',I5)
311   FORMAT(10X,'DENOMINATOR ORDER =',I5)
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)
330   FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)
350   FORMAT(5X,'  FREQUENCY ',3X,'  MAGNITUDE ',3X,' PHASE      ',
     * 3X,'     REAL     ',3X,'   IMAGINARY',
     */,5X,'  (RAD/SEC) ',3X,'              ',3X,' (DEGREES)',
     * 3X,'     PART     ',3X,'     PART     ')
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,
     *10X,'TYPE "YES" OR "NO".',/)
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,
     *10X,'1.  OUTPUT DEVICE',/,
     *10X,'2.  FREQUENCY RANGE',/,
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,
     *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,
     *10X,'5.  EXIT NYQUIST TABULAR DATA ROUTINE',/)
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ',
     *3X,'ENTER "YES" OR "NO".',/)
501   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ',
     *3X,'ENTER "YES" TO CONTINUE',/)
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TO ZER
     *O',/)
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)
C-----------------------------------------------------------------------
      END
```

```
C=========================================================================
C=========================================================================
      SUBROUTINE NICHOL (NS,K2,K1,ITFX)
C     INTERATIVELY PLOTS A NICHOLS PLOT USING CISSPLA GRAPHICS GIVEN
C     THE ZERO AND POLE LOCATIONS
C=========================================================================
      REAL*8 OLN,CLD,ORNUM,CI,QR,QPSR,MAG,GAN,CO,MA,OMEGA
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,
     *PAGEY,XX,YY,COL,FL,FU,PM,GM,C2,C3,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,
     *PMIN,PMAX,RL,B1,B2,B3,TH1,T9,T10
      COMPLEX*16 RTN,PLN,RTD,PLD,WN
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,IPP,CRD,PTS,
     *KK,J,II,N1,IPT,ITFX
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CC
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)
      COMMON /SHEAD/ LINES(4,18),LINE(9)
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),CI(500),
     *CR(500),QPSR(500),MAG(500)
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10
      DATA IY/'Y'/,IZ/'N'/
C----------------------GRAPHIC OR TABULAR OUTPUT-------------------------
200   CALL FRTCMS('CLRSCRN ')
      WRITE(6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
      CALL PRTPLT(IPP)
      GO TO (201,202,80),IPP
C---------------------------------------------PLOT SETUP-----------------
201   CONTINUE
      N = 500
      ICHG = 0
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95
40    CALL FRTCMS('CLRSCRN ')
      IF(ICHG.EQ.1) GO TO 41
      WRITE (6,120)
      IF(ITFX.EQ.1) WRITE(6,710)
      IF(ITFX.EQ.2) WRITE(6,711)
      IF(ITFX.EQ.3) WRITE(6,712)
41    CALL GSETUP(IPTR,PAGEX,PAGEY)
      IF(ICHG.EQ.1) GO TO 90
50    CALL FRTCMS('CLRSCRN ')
      CALL FGRAF(FMIN,FMAX)
      IF(ICHG.EQ.1) GO TO 90
60    CALL FRTCMS('CLRSCRN ')
      CALL GHEAD(NL)
      IF(ICHG.EQ.1) GO TO 90
70    CONTINUE
```

```
C-----------------------------------------SCALING CONSTANTS-------------OPT16330
      CALL PSCALE(PAGEX)                                                OPT16340
C-------------------------------------------INPUT ARRAYS----------------OPT16350
      GOL  = SNGL(GAN(2,K2,K1))                                         OPT16360
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT16370
      DO 5 I =1,N                                                       OPT16380
      MA = 20.0*DLOG10(MAG(I))                                          OPT16390
      YDO(I) = SNGL(MA)                                                 OPT16400
      XDO(I) = SNGL(QPSR(I))                                            OPT16410
5     CONTINUE                                                          OPT16420
      CALL MINMAX(N,YDO,MMIN,MMAX)                                      OPT16430
      CALL MINMAX(N,XDO,PMIN,PMAX)                                      OPT16440
C-----------------------------------------PLOT LIMITS-------------------OPT16450
      XAXIS = PAGEX -2.*T1                                              OPT16460
      YAXIS = PAGEY -T1 -T2                                             OPT16470
      IF(MMAX.LT.0.0) MMAX = 0.0                                        OPT16480
      IF(MMIN.GT.0.0) MMIN = 0.0                                        OPT16490
      IF(PMAX.LT.0.0) PMAX = 0.0                                        OPT16500
      IF(PMIN.GT.0.0) PMIN = 0.0                                        OPT16510
C-----------------------------------------TEK 618-----------------------OPT16520
      IF(IPTR.EQ.2) GO TO 10                                            OPT16530
      CALL TEK618                                                       OPT16540
      CALL PAGE(PAGEX,PAGEY)                                            OPT16550
      CALL HWROT('AUTO')                                                OPT16560
      CALL HWSCAL('SCREEN')                                             OPT16570
      CALL NOBRDR                                                       OPT16580
      GO TO 20                                                          OPT16590
C-----------------------------------------COMPRS------------------------OPT16600
10    CONTINUE                                                          OPT16610
      CALL COMPRS                                                       OPT16620
      CALL PAGE(PAGEX,PAGEY)                                            OPT16630
20    CONTINUE                                                          OPT16640
C-------------------------------------------PLOT EXECUTION--------------OPT16650
      CALL NOCHEK                                                       OPT16660
      CALL GRACE(0.)                                                    OPT16670
      CALL PHYSOR(T1,T1)                                                OPT16680
      CALL AREA2D(XAXIS, YAXIS)                                         OPT16690
      CALL TRIPLX                                                       OPT16700
      CALL HEIGHT(TH)                                                   OPT16710
      CALL XNAME('PHASE - DEGREES $',100)                               OPT16720
      CALL HEIGHT(TH)                                                   OPT16730
      CALL YNAME('MAGNITUDE - DECIBELS $',100)                          OPT16740
      CALL GRAF(FMIN,'SCALE',PMAX,MMIN,'SCALE',MMAX)                    OPT16750
C-----------------------------------------HEADING-----------------------OPT16760
      NN = NL + 1                                                       OPT16770
      IF(NL.EQ.0) GO TO 35                                              OPT16780
      DO 35 I=1,NL                                                      OPT16790
         CALL CLINE(I)                                                  OPT16800
         CALL HEADIN(LINE,100,T3,NN)                                      OPT16810
35     CONTINUE                                                           OPT16820
       IF(ITFX.EQ.1)                                                      OPT16830
     *    CALL HEADIN('OPEN LOOP TRANSFER NICHOLS$',100,T3,NN)            OPT16840
       IF(ITFX.EQ.2)                                                      OPT16850
     *    CALL HEADIN('NOISE TRANSFER NICHOLS$',100,T3,NN)                OPT16860
       IF(ITFX.EQ.3)                                                      OPT16870
     *    CALL HEADIN('COMPENSATOR TRANSFEP NICHOLS$',100,T3,NN)          OPT16880
C------------------------------------CURVE PLCT-------------------------OPT16890
       CALL CURVE(XDO,YDO,N,0)                                            OPT16900
C------------------------------------LEGEND-----------------------------OPT16910
       XX = XAXIS - T7                                                    OPT16920
       YY = YAXIS + T8                                                    OPT16930
       CALL HEIGHT(TH1)                                                   OPT16940
       CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                    OPT16950
       CALL HEIGHT(TH1)                                                   OPT16960
       CALL INTNO(K1,'ABUT','ABUT')                                       OPT16970
       CALL HEIGHT(TH1)                                                   OPT16980
       CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                     OPT16990
       CALL HEIGHT(TH1)                                                   OPT17000
       CALL INTNO(K2,'ABUT','ABUT')                                       OPT17010
       CALL HEIGHT(TH1)                                                   OPT17020
       CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                          OPT17030
       CALL HEIGHT(TH1)                                                   OPT17040
       CALL REALNC(GDL,-3,'ABUT','ABUT')                                  OPT17050
       CALL BLREC(XX,YY,T5,T6,0.02)                                       OPT17060
C-----------------------------------------------------------------------OPT17070
C------------------------------------GRID-------------------------------OPT17080
       CALL DOT                                                           OPT17090
       CALL GRID(1,1)                                                     OPT17100
       CALL RESET('DOT')                                                  OPT17110
       CALL ENDPL(0)                                                      OPT17120
       IF(IPTR.NE.2) GO TO 75                                             OPT17130
       CALL FRTCMS('CLRSCRN ')                                            OPT17140
       WRITE(6,130)                                                       OPT17150
C------------------------------------GAIN AND PHASE MARGIN--------------OPT17160
75     DO 73 I =1,N                                                       OPT17170
       OMEGA = DIMAG(WN(I))                                               OPT17180
       XNO(I) = SNGL(OMEGA)                                               OPT17190
       MA = 20.0*DLOG10(MAG(I))                                           OPT17200
       YNO(I) = SNGL(MA)                                                  OPT17210
       YDO(I) = SNGL(QPSR(I))                                             OPT17220
73     CONTINUE                                                           OPT17230
       CALL FRTCMS('CLRSCRN ')                                            OPT17240
       WRITE(6,135)                                                       OPT17250
C------------------------------------GAIN MARGIN------------------------OPT17260
       DO 71 I = 2,N                                                      OPT17270
       IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72       OPT17280
```

```
      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72       OPT17290
      GO TO 71                                                           OPT17300
72    GM = 0.0 - YNO(I)                                                  OPT17310
      WRITE (6,140) XNO(I), GM                                           OPT17320
71    CONTINUE                                                           OPT17330
C-----------------------------------PHASE MARGIN-------------------------OPT17340
      DO 76 I = 2,N                                                      OPT17350
      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                     OPT17360
      GO TO 76                                                           OPT17370
77    PM = 180.0 + YDO(I)                                                OPT17380
      WRITE (6,150) XNO(I), PM                                           OPT17390
76    CONTINUE                                                           OPT17400
      WRITE(6,160)                                                       OPT17410
C-----------------------------------CHANGES TO PLOT----------------------OPT17420
90    CONTINUE                                                           OPT17430
      CALL FRTCMS('CLRSCRN ')                                            OPT17440
      WRITE(6,120)                                                       OPT17450
      IF(ITFX.EQ.1) WRITE(6,710)                                         OPT17460
      IF(ITFX.EQ.2) WRITE(6,711)                                         OPT17470
      IF(ITFX.EQ.3) WRITE(6,712)                                         OPT17480
      WRITE(6,100)                                                       OPT17490
30    WRITE(6,110)                                                       OPT17500
      CALL RDINT(IANS)                                                   OPT17510
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                                OPT17520
      GO TO 25                                                           OPT17530
15    WRITE(6,510)                                                       OPT17540
      GO TO 30                                                           OPT17550
25    CONTINUE                                                           OPT17560
      ICHG = 1                                                           OPT17570
      GO TO (40,50,60,70,200),IANS                                       OPT17580
C-----------------------------------TABULAR DATA-------------------------OPT17590
202   CONTINUE                                                           OPT17600
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                   OPT17610
      ICHG =0                                                            OPT17620
251   CALL FRTCMS('CLRSCRN ')                                            OPT17630
      IF(ICHG.EQ.1) GO TO 249                                            OPT17640
      WRITE(6,120)                                                       OPT17650
      IF(ITFX.EQ.1) WRITE(6,710)                                         OPT17660
      IF(ITFX.EQ.2) WRITE(6,711)                                         OPT17670
      IF(ITFX.EQ.2) WRITE(6,712)                                         OPT17680
249   CALL PRTR(IPT)                                                     OPT17690
      IF(ICHG.EQ.1) GO TO 290                                            OPT17700
252   CALL FRTCMS('CLRSCRN ')                                            OPT17710
      CALL FGRAF(FMIN,FMAX)                                              OPT17720
      IF(ICHG.EQ.1) GO TO 290                                            OPT17730
253   CALL FRTCMS('CLRSCRN ')                                            OPT17740
      CALL NPTS(FTS)                                                     OPT17750
      IF(ICHG.EQ.1) GO TO 290                                            OPT17760
```

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C----------------------------------------TABULATE CATA-----------------OPT17770
254    CCNTINUE                                                          OPT17780
       ZERO = 0.0                                                        OPT17790
       J1 = 0                                                            OPT17800
       ORD = CINT(GAN(1,K2,K1))                                          OPT17810
       GAIN = GAN(2,K2,K1)                                               OPT17820
       CALL FRTCMS('CLRSCRN ')                                           OPT17830
       WRITE(IPT,120)                                                    OPT17840
       IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT17850
       IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT17860
       IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT17870
       WRITE(IPT,300) K1                                                 OPT17880
       WRITE(IPT,301) K2                                                 OPT17890
       WRITE(IPT,311) NS                                                 OPT17900
       WRITE(IPT,310) ORD                                                OPT17910
       WRITE(IPT,320) GAN(2,K2,K1)                                       OPT17920
       WRITE(IPT,350)                                                    OPT17930
       N = PTS                                                           OPT17940
       CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT17950
       DO 220 I = 1,N                                                    OPT17960
       OMEGA = DIMAG(WN(I))                                              OPT17970
       MA = 20.0*DLOG10(MAG(I))                                          OPT17980
       WRITE(IPT,330) OMEGA,MA,QPSR(I),QR(I),QI(I)                       OPT17990
220    CONTINUE                                                          OPT18000
C----------------------------------------CHANGES TABULAR DATA----------OPT18010
240    IF(IPT.EQ.3) WRITE (6,401)                                        OPT18020
       IF(IPT.EQ.2) WRITE (6,402)                                        OPT18030
       WRITE(6,400)                                                      OPT18040
       CALL RDCHAR (IANS)                                                OPT18050
       IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT18060
       GO TO 250                                                         OPT18070
245    WRITE (6,500)                                                     OPT18080
       GO TO 240                                                         OPT18090
250    CCNTINUE                                                          OPT18100
       IF (IANS.EQ.IY) GO TC 290                                         OPT18110
       IF (IANS.EQ.IZ) GO TC 200                                         OPT18120
C----------------------------------------CHANGES -----------------------OPT18130
290    CCNTINUE                                                          OPT18140
       CALL FRTCMS('CLRSCRN ')                                           OPT18150
       WRITE(6,120)                                                      OPT18160
       IF(ITFX.EQ.1) WRITE(6,710)                                        OPT18170
       IF(ITFX.EQ.2) WRITE(6,711)                                        OPT18180
       IF(ITFX.EQ.3) WRITE(6,712)                                        OPT18190
       WRITE(6,410)                                                      OPT18200
291    WRITE(6,110)                                                      OPT18210
       CALL RCINT(IANS)                                                  OPT18220
       IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT18230
       GO TO 293                                                         OPT18240
```

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292    WRITE(6,510)                                                       OPT18250
       GO TO 291                                                          OPT18260
293    CONTINUE                                                           OPT18270
       ICHG = 1                                                           OPT18280
       GO TO (251,252,253,254,200),IANS                                   OPT18290
C-------------------------------------------------------------------------OPT18300
90     RETURN                                                             OPT18310
95     WRITE(6,520)                                                       OPT18320
       RETURN                                                             OPT18330
C-------------------------------------------------------------------------OPT18340
100    FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT18350
      *LOTTER / PAGE SIZE',/,10X,'2.  FREQUENCY RANGE',/,10X,'3.  HEADINGOPT18360
      *',/,10X,'4.  NO ADDITIONAL CHANGES - PLOT NICHOLS PLOTS',/,10X,    OPT18370
      *'5.  NO CHANGES - EXIT NICHOLS PLOTTING ROUTINE',/)                OPT18380
110    FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                              OPT18390
120    FORMAT(//,15X,'NICHOLS PLOT')                                      OPT18400
130    FORMAT(////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,       OPT18410
      *15X,'CLEAR SCREEN TO CONTINUE',////////////////////)               OPT18420
135    FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)                  OPT18430
140    FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC:'1X,    OPT18440
      *'GAIN MARGIN IS ',F10.4,' DB')                                     OPT18450
150    FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC:',1X,   OPT18460
      *,'PHASE MARGIN IS',F10.4,' DEG')                                   OPT18470
160    FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',//////////////////////)   OPT18480
300    FORMAT(//,10X,'INPUT NUMBER =      ',I5)                           OPT18490
301    FORMAT(10X,'OUTPUT NUMBER =     ',I5)                              OPT18500
310    FORMAT(10X,'NUMERATOR ORDER =   ',I5)                              OPT18510
311    FORMAT(10X,'DENOMINATOR ORDER =',I5)                               OPT18520
320    FORMAT(10X,'TRANSFER FUNCTION GAIN =',D12.4,/)                     OPT18530
330    FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)               OPT18540
350    FORMAT(5X,'  FREQUENCY ',3X,'  MAGNITUDE ',3X,' PHASE      ',      OPT18550
      * 3X,'    REAL    ',3X,'  IMAGINARY',                               OPT18560
      */,5X,'  (RAD/SEC) ',3X,'            ',3X,' (DEGREES)',             OPT18570
      * 3X,'    PART    ',3X,'    PART     ')                             OPT18580
400    FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,              OPT18590
      *10X,'TYPE "YES" OR "NO".',/)                                       OPT18600
401    FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                         OPT18610
402    FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                    OPT18620
410    FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,           OPT18630
      *10X,'1.  OUTPUT DEVICE',/,                                         OPT18640
      *10X,'2.  FREQUENCY RANGE',/,                                       OPT18650
      *10X,'3.  NUMBER OF POINTS CALCULATED',/,                           OPT18660
      *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,                 OPT18670
      *10X,'5.  EXIT BODE TABULAR DATA ROUTINE',/)                        OPT18680
500    FORMAT(/,5X,'***** WARNING *****',/,5X,'IMPROPER DATA ENTRY    ', OPT18690
      *3X,'ENTER "YES" OR "NO".',/)                                       OPT18700
501    FORMAT(/,5X,'***** WARNING *****',/,5X,'IMPROPER DATA ENTRY    ', OPT18710
      *3X,'ENTER "YES" TO CONTINUE',/)                                    OPT18720
```

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510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)      OPT18730
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TO ZEROPT18740
     *O',/)                                                              OPT18750
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                         OPT18760
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                             OPT18770
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                       OPT18780
C-----------------------------------------------------------------------OPT18790
      END                                                                OPT18800
C=======================================================================OPT18810
C=======================================================================OPT18820
      SUBROUTINE FREQ(NS,K2,K1,FMIN,FMAX,NN)                             OPT18830
C     THE SUBROUTINE FREQ CALCULATES THE MAGNITUDE AND PHASE FOR THE     OPT18840
C     BODE, NYQUIST, AND NICHOLS RESPONSES                               OPT18850
C=======================================================================OPT18860
      REAL*8 OLD,CLN,MAG,QI,QR,QPSR,FRMAX,FRMIN,CYCLE,ZERO,XX,AA,GAIN,   OPT18870
     *DELTF,GAN,CO                                                       OPT18880
      REAL*4 FMAX, FMIN                                                  OPT18890
      COMPLEX*16 RTN,PLN,RTD,PLD,CPOLN,WN,CPOLD,CPCL                     OPT18900
      INTEGER I,J1,K2,K1,NS,IPHS,JJ,L,N,N1,N2,NN,ORD                     OPT18910
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO           OPT18920
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),    OPT18930
     *QP(500),QPSF(500),MAG(500)                                         OPT18940
C-----------------------------------------------------------------------OPT18950
C--------------------------------------NUMERATOR / DENOMINATOR------OPT18960
      AA = DFLOAT(NN)                                                    OPT18970
      J1= 0                                                              OPT18980
      DO 4 I = 1,NS                                                      OPT18990
      RTN(I) = 0.0                                                       OPT19000
      RTD(I) =0.0                                                        OPT19010
4     CONTINUE                                                           OPT19020
      DO 10 I = 1,NS                                                     OPT19030
      IF((DABS(OLN(I,1,K2,K1)).LE.CO).AND.(DABS(OLN(I,2,K2,K1)).LE.CO)) OPT19040
     * GO TO 20                                                          OPT19050
      J1= J1+1                                                           OPT19060
      RTN(J1) = DCMPLX(OLN(I,1,K2,K1),OLN(I,2,K2,K1))                    OPT19070
20    CONTINUE                                                           OPT19080
      RTD(I) = DCMPLX(OLD(I,1),OLD(I,2))                                 OPT19090
10    CONTINUE                                                           OPT19100
      ORD = DINT(GAN(1,K2,K1))                                           OPT19110
      IF(ORD.GT.J1) J1 = ORD                                             OPT19120
C--------------------------------------TRANSFER FUNCTION MATH ------OPT19130
      ZERO = 0.0                                                         OPT19140
      GAIN = GAN(2,K2,K1)                                                OPT19150
      IPHS = 0                                                           OPT19160
C--------------------------------------INCREMENT FREQUENCY----------OPT19170
      FRMAX = DBLE(FMAX)                                                 OPT19180
      FRMIN = DBLE(FMIN)                                                 OPT19190
      CYCLE = (DLOG10(FRMAX) - DLOG10(FRMIN))/(AA - 1.)                  OPT19200
      DELTF = 10.**CYCLE                                                OPT19210
      DO 80 I = 1,NN                                                    OPT19220
      IF(I.GT.1)GO TO 5                                                 OPT19230
      WN(1) = DCMPLX(ZERO,FRMIN)                                        OPT19240
      GO TO 6                                                           OPT19250
5     WN(I) = WN(I-1) * DELTF                                           OPT19260
C---------------------------------------POLYNOMIAL-----------------OPT19270
6     CPOL = 1.                                                         OPT19280
      IF(J1.EQ.0) GO TO 7                                               OPT19290
      DO 30 K = 1,J1                                                    OPT19300
30    CPOL = CPOL*(WN(I)-RTN(K))/(WN(I)-RTD(K))                         OPT19310
      IF(J1.EQ.NS) GO TO 8                                              OPT19320
7     JJ = J1 + 1                                                       OPT19330
9     DO 40 K = JJ,NS                                                   OPT19340
40    CPOL = CPOL/(WN(I)-RTD(K))                                        OPT19350
8     CPOL = CPOL*GAIN                                                  OPT19360
C---------------------------------------MAGNITUDE------------------OPT19370
      MAG(I) = CDABS(CPOL)                                              OPT19380
C---------------------------------------PHASE----------------------OPT19390
      QI(I) = DIMAG(CPOL)                                               OPT19400
      QR(I) = DREAL(CPOL)                                               OPT19410
600   IF(QI(I)) 601,602,603                                             OPT19420
601   IF(QR(I)) 620,621,622                                             OPT19430
602   IF(QR(I)) 623,751,625                                             OPT19440
603   IF(QR(I)) 626,627,628                                             OPT19450
620   QPSR(I) = -180.+ 57.29577951*DATAN(QI(I)/QR(I))                   OPT19460
      GO TO 555                                                         OPT19470
621   QPSR(I) = -90.                                                    OPT19480
      GO TO 555                                                         OPT19490
622   QPSR(I) = - 57.29577951*DATAN(-QI(I)/QR(I))                       OPT19500
      GO TO 555                                                         OPT19510
623   QPSR(I) = 180.                                                    OPT19520
      GO TO 555                                                         OPT19530
625   QPSR(I) = 0.0                                                     OPT19540
      GO TO 555                                                         OPT19550
626   QPSR(I) = 180.- 57.29577951*DATAN(-QI(I)/QR(I))                   OPT19560
      GO TO 555                                                         OPT19570
627   QPSR(I) = 90.                                                     OPT19580
      GO TO 555                                                         OPT19590
628   QPSR(I) =  57.29577951*DATAN(QI(I)/QR(I))                         OPT19600
      GO TO 555                                                         OPT19610
555   IF(IPHS.EQ.1) GO TO 640                                           OPT19620
      IF((QPSR(I-1).GT.90.).AND.(QPSR(I).LT.-90.)) GO TO 630            OPT19630
      IF((QPSR(I-1).LT.-90.).AND.(QPSR(I).GT.90.)) IPHS = 1             OPT19640
      GO TO 640                                                         OPT19650
630   N = I - 1                                                         OPT19660
      DO 650 L = 1, N                                                   OPT19670
      QPSR(L) = QPSR(L) - 360.                                          OPT19680
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650   CONTINUE
640   IF(IPHS.EQ.0) GO TO 700
      QPSR(I) = CFSR(I) - 360.
700   CONTINUE
80    CONTINUE
      RETURN
751   WRITE(6,752)
      RETURN
C-----------------------------------------------------------------------
752   FORMAT (/,5X,'****** PROGRAM FAILURE COMPUTING FREQUENCY ******')
C-----------------------------------------------------------------------
      END
C=======================================================================
C=======================================================================
      SUBROUTINE GSETUP(IPTR,PAGEX,PAGEY)
C     SUBROUTINE GSETUP INTERACTIVELY ALLOWS THE USER TO SELECT EITHER
C     THE TEK618 OR VERSATEC PLOTTER AND SPECIFY A PAGE SIZE
C=======================================================================
      INTEGER IPTR,IANS
      REAL*8 ANSR
      REAL*4 PAGEX,PAGEY
C------------------------------------------PLOTTER SELECTION------------
      WRITE(6,100)
10    WRITE(6,110)
      CALL RDINT(IANS)
      IF(IANS.LT.1.OR.IANS.GT.2) GO TO 20
      GO TO 30
20    WRITE(6,500)
      GO TO 10
30    CONTINUE
      IPTR = IANS
      IF(IPTR.EQ.1) GO TO 80
C----------------------------------------VRSTEC PAGE SIZE---------------
      CALL FRTCMS('CLRSCRN ')
C----------------------------------------HEIGHT-------------------------
      WRITE(6,130)
40    WRITE(6,140)
      CALL RDREAL(ANSR)
      IF(ANSR.LT.0.0.OR.IANS.GT.21.0) GO TO 45
      GO TO 50
45    WRITE(6,510)
      GO TO 40
50    CONTINUE
      PAGEY = ANSR
C----------------------------------------WIDTH--------------------------
60    WRITE(6,150)
      CALL RDREAL(ANSR)
      IF(ANSR.LT.0.0.OR.IANS.GT.21.0) GO TO 65
      GO TO 70
65    WRITE(6,510)
      GO TO 60
70    CONTINUE
      PAGEX = ANSR
      RETURN
C-------------------------------------------VRSTEC PAGE SIZE--------------
80    CONTINUE
      PAGEX = 11.0
      PAGEY = 8.5
      RETURN
C-------------------------------------------------------------------------
100   FORMAT(//,5X,'PLOTTER SELECTION AND PAGE SIZE',/,5X,
     *'(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH SELECTION OF TEK618
     *)',//)
110   FORMAT(/,10X,'WHICH PLOTTER DO YOU DESIRE:',//,15X,'1. TEK618',/,
     *15X,'2. VERSATEC',//,10X,'CHOOSE OPTION 1 OR 2')
130   FORMAT(//,10X,' PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0 INCHES)'
     *,/)
140   FORMAT(/,15X,'HEIGHT =',//)
150   FORMAT(/,15X,'WIDTH =',//)
500   FORMAT(//,5X,'***** ERROR ENTER 1 OR 2 *****',//)
510   FORMAT(//,5X,'***** ERROR MAXIMUM = 21 INCHES *****',//)
      END
C=========================================================================
C=========================================================================
      SUBROUTINE GGRAF(XMIN,XMAX,YMIN,YMAX)
C     SUBROUTINE GGRAF INTERACTIVELY ALLOWS THE USER TO SELECT PLOTTING
C     LIMITS FOR USE WITH DISSPLA GRAPHICS
C=========================================================================
      REAL XMIN,XMAX,YMIN,YMAX,ANSR
      DATA IY/'Y'/,IZ/'N'/
C-------------------------------------------------------------------------
40    CONTINUE
      WRITE(6,100)
      WRITE(6,105)
C---------------------------------------------------XMIN------------------
      WRITE(6,110)
      CALL RDREAL(ANSR)
         XMIN = ANSR
C---------------------------------------------------XMAX------------------
      WRITE(6,120)
      CALL RDREAL(ANSR)
         XMAX = ANSR
C---------------------------------------------------YAXIS-----------------
      WRITE(6,125)
C---------------------------------------------------YMIN------------------
      WRITE(6,130)
      CALL RDREAL(ANSR)                                                 OPT20650
         YMIN = ANSR                                                    OPT20660
C---------------------------------------YMAX---------------------------OPT20670
      WRITE(6,140)                                                      OPT20680
      CALL RDREAL(ANSR)                                                 OPT20690
         YMAX = ANSR                                                    OPT20700
C---------------------------------------CORRECTIONS--------------------OPT20710
      CALL FRTCMS('CLRSCRN ')                                           OPT20720
      WRITE(6,100)                                                      OPT20730
      WRITE(6,105)                                                      OPT20740
      WRITE(6,150) XMIN                                                 OPT20750
      WRITE(6,160) XMAX                                                 OPT20760
      WRITE(6,125)                                                      OPT20770
      WRITE(6,170) YMIN                                                 OPT20780
      WRITE(6,180) YMAX                                                 OPT20790
30    WRITE(6,190)                                                      OPT20800
      CALL RDCHAR(IANS)                                                 OPT20810
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10                        OPT20820
      GO TO 20                                                          OPT20830
10    WRITE(6,500)                                                      OPT20840
      GO TO 30                                                          OPT20850
20    CONTINUE                                                          OPT20860
      IF(IANS.EQ.IY) GO TO 40                                           OPT20870
      RETURN                                                            OPT20880
C----------------------------------------------------------------------OPT20890
100   FORMAT(//,5X,'PLOTTING LIMITS FOR GRAPH',/)                       OPT20900
105   FORMAT(10X,'X AXIS (REAL AXIS)',/)                                OPT20910
110   FORMAT(15X,'X MINIMUM = ?',/)                                     OPT20920
120   FORMAT(15X,'X MAXIMUM = ?',/)                                     OPT20930
125   FORMAT(10X,'Y AXIS (IMAGINARY AXIS)',/)                           OPT20940
130   FORMAT(15X,'Y MINIMUM = ?',/)                                     OPT20950
140   FORMAT(15X,'Y MAXIMUM = ?',/)                                     OPT20960
150   FORMAT(15X,'X MINIMUM = ',F8.2,/)                                 OPT20970
160   FORMAT(15X,'X MAXIMUM = ',F8.2,/)                                 OPT20980
170   FORMAT(15X,'Y MINIMUM = ',F8.2,/)                                 OPT20990
180   FORMAT(15X,'Y MAXIMUM = ',F8.2,/)                                 OPT21000
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,          OPT21010
     *'TYPE "YES" OR "NO".',//)                                         OPT21020
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT21030
     *3X,'ENTER "YES" OR "NO".',/)                                      OPT21040
      END                                                               OPT21050
C======================================================================OPT21060
C======================================================================OPT21070
      SUBROUTINE FGRAF(FMIN,FMAX)                                       OPT21080
C     SUBROUTINE FGRAF INTERACTIVELY ALLOWS THE USER TO SELECT PLOTTING OPT21090
C     LIMITS FOR USE WITH DISSPLA GRAPHICS                              OPT21100
C======================================================================OPT21110
      REAL FMIN,FMAX                                                    OPT21120
      DATA IY/'Y'/,IZ/'N'/                                              OPT21130
C-----------------------------------------------------------------------OPT21140
40    CONTINUE                                                          OPT21150
      WRITE(6,100)                                                      OPT21160
      WRITE(6,105)                                                      OPT21170
C----------------------------------------FMIN---------------------------OPT21180
50    WRITE(6,110)                                                      OPT21190
      CALL RDREAL(ANSR)                                                 OPT21200
         FMIN = ANSR                                                    OPT21210
      IF(FMIN.GT.0.0) GO TO 60                                          OPT21220
         WRITE(6,510)                                                   OPT21230
         GO TO 50                                                       OPT21240
C----------------------------------------FMAX---------------------------OPT21250
60    WRITE(6,120)                                                      OPT21260
      CALL RDREAL(ANSR)                                                 OPT21270
         FMAX = ANSR                                                    OPT21280
      IF(FMAX.GT.0.0) GO TO 70                                          OPT21290
         WRITE(6,510)                                                   OPT21300
         GO TO 60                                                       OPT21310
C----------------------------------------CORRECTIONS--------------------OPT21320
70    CALL FRTCMS('CLRSCRN ')                                           OPT21330
      WRITE(6,100)                                                      OPT21340
      WRITE(6,105)                                                      OPT21350
      WRITE(6,150) FMIN                                                 OPT21360
      WRITE(6,160) FMAX                                                 OPT21370
30    WRITE(6,190)                                                      OPT21380
      CALL RDCHAR(IANS)                                                 OPT21390
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10                        OPT21400
      GO TO 20                                                          OPT21410
10    WRITE(5,500)                                                      OPT21420
      GO TO 30                                                          OPT21430
20    CONTINUE                                                          OPT21440
      IF(IANS.EQ.IY) GO TO 40                                           OPT21450
      RETURN                                                            OPT21460
C-----------------------------------------------------------------------OPT21470
100   FORMAT(//,5X,'PLOTTING LIMITS FOR GRAPH',/)                       OPT21480
105   FORMAT(10X,'FREQUENCY RANGE - RADIANS PER SECOND',/)              OPT21490
110   FORMAT(15X,'MINIMUM FREQUENCY = ?',/)                             OPT21500
120   FORMAT(15X,'MAXIMUM FREQUENCY = ?',/)                             OPT21510
150   FORMAT(15X,'MINIMUM FREQUENCY = ',E15.3,/)                        OPT21520
160   FORMAT(15X,'MAXIMUM FREQUENCY = ',E15.3,/)                        OPT21530
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,          OPT21540
     *'TYPE "YES" OR "NO".',//)                                         OPT21550
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',OPT21560
     *3X,'ENTER "YES" OR "NO".',/)                                      OPT21570
510   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',OPT21580
     *3X,'FREQUENCY MUST BE GREATER THAN ZERO.',/)                      OPT21590
      END                                                               OPT21600
```

```
C=======================================================================
C=======================================================================
      SUBROUTINE RANGK(KMIN,KMAX)
C     SUBROUTINE RANGK INTERACTIVELY ALLOWS THE USER TO SELECT GAIN
C     LIMITS FOR USE WITH ROOT-LOCUS PLOTS
C=======================================================================
      REAL*8 KMIN,KMAX
      DATA IY/'Y'/,IZ/'N'/
C-----------------------------------------------------------------------
40    CONTINUE
      WRITE(6,100)
C-----------------------------------------KMIN--------------------------
50    WRITE(6,110)
      CALL RDREAL(ANSR)
         KMIN = ANSR
C-----------------------------------------KMAX--------------------------
60    WRITE(6,120)
      CALL RDREAL(ANSR)
         KMAX = ANSR
C-----------------------------------------CORRECTIONS-------------------
70    CALL FRTCMS('CLRSCRN ')
      WRITE(6,100)
      WRITE(6,150) KMIN
      WRITE(6,160) KMAX
30    WRITE(6,190)
      CALL RDCHAR(IANS)
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10
      GO TO 20
10    WRITE(5,500)
      GO TO 30
20    CONTINUE
      IF(IANS.EQ.IY) GO TO 40
      RETURN
C-----------------------------------------------------------------------
100   FORMAT(//,5X,'GAIN RANGE FOR ROOT-LOCUS PLOT',//)
110   FORMAT(15X,'MINIMUM GAIN = ?',/)
120   FORMAT(15X,'MAXIMUM GAIN = ?',/)
150   FORMAT(15X,'MINIMUM GAIN = ',E15.3,/)
160   FORMAT(15X,'MAXIMUM GAIN = ',E15.3,/)
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,
     *'TYPE "YES" OR "NO".',//)
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY    ',
     *3X,'ENTER "YES" OR "NO".',/)
      END
C=======================================================================
C=======================================================================
      SUBROUTINE CHEAD(NL)
C     SUBROUTINE CHEAD INTERACTIVELY ALLOWS THE USER TO INPUT THREE
```

```
C     LINES OF HEADING FOR USE WITH DISSPLA GRAPHICS                    OPT22090
C=======================================================================OPT22100
      INTEGER NL,LINES,I,IANS,LINE                                      OPT22110
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT22120
      DATA IY/'Y'/,IZ/'N'/                                              OPT22130
C-----------------------------------------------------------------------OPT22140
      WRITE(6,100)                                                      OPT22150
10    WRITE(6,110)                                                      OPT22160
      CALL RDINT(IANS)                                                  OPT22170
      IF(IANS.GT.3) GO TO 30                                            OPT22180
      GO TO 20                                                          OPT22190
30    WRITE(6,510)                                                      OPT22200
      GO TO 10                                                          OPT22210
20    CONTINUE                                                          OPT22220
      IF(IANS.LT.0) GO TO 35                                            OPT22230
      GO TO 25                                                          OPT22240
35    WRITE(6,520)                                                      OPT22250
      GO TO 10                                                          OPT22260
25    CONTINUE                                                          OPT22270
      NL = IANS                                                         OPT22280
      IF(NL.EQ.0) GO TO 70                                              OPT22290
      WRITE(6,120)                                                      OPT22300
      DO 50 I = 1,NL                                                    OPT22310
         WRITE(6,130) I                                                 OPT22320
         CALL RLINE(I)                                                  OPT22330
50    CONTINUE                                                          OPT22340
C-----------------------------------------CORRECTIONS-------------------OPT22350
80    CALL FRTCMS('CLRSCRN ')                                           OPT22360
      WRITE(6,100)                                                      OPT22370
      DO 60 I = 1,NL                                                    OPT22380
         WRITE(6,140) I,(LINES(I,J),J=1,9)                              OPT22390
60    CONTINUE                                                          OPT22400
63    WRITE(6,150)                                                      OPT22410
      CALL RDCHAR(IANS)                                                 OPT22420
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 61                        OPT22430
      GO TO 62                                                          OPT22440
61    WRITE(6,500)                                                      OPT22450
      GO TO 63                                                          OPT22460
62    CONTINUE                                                          OPT22470
      IF(IANS.EQ.IZ) GO TO 70                                           OPT22480
77    WRITE(6,160)                                                      OPT22490
      CALL RDINT(IANS)                                                  OPT22500
         IF((IANS.LT.1).OR.(IANS.GT.NL)) GO TO 75                       OPT22510
         GO TO 76                                                       OPT22520
75    CONTINUE                                                          OPT22530
         WRITE(6,530)                                                   OPT22540
         GO TO 77                                                       OPT22550
76    CONTINUE                                                          OPT22560
```

```
      WRITE(6,130) IANS                                                 OPT22570
      CALL RLINE(IANS)                                                  OPT22580
      GO TO 80                                                          OPT22590
70    CONTINUE                                                          OPT22600
      RETURN                                                            OPT22610
C-----------------------------------------------------------------------OPT22620
100   FORMAT(//,5X,'PLOT HEADING',/)                                    OPT22630
110   FORMAT(/,10X,'HOW MANY LINES OF HEADING DO YOU DESIRE ? ( 3 MAX )'OPT22640
     *,/,15X,'ENTER NUMBER OF LINES.  ( ENTER "0" FOR NO HEADING )',/)  OPT22650
120   FORMAT(/,10X,'A MAXIMUM OF 32 CHARACTERS PER LINE IS ALLOWED',/)  OPT22660
130   FORMAT(/,10X,'LINE',I2,' IS:',/)                                  OPT22670
140   FORMAT(/,10X,'LINE',I2,' :',5X,9A4,/)                             OPT22680
150   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,          OPT22690
     *'TYPE "YES" OR "NO".',//)                                         OPT22700
160   FORMAT(/,5X,'ENTER LINE NUMBER TO BE CHANGED.',/)                 OPT22710
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT22720
     *3X,'ENTER "YES" OR "NO".',/)                                      OPT22730
510   FORMAT(/,5X,'****** ERROR: 3 LINES MAXIMUM ******',/)             OPT22740
520   FORMAT(/,5X,'****** ERROR: 0 LINES MINIMUM ******',/)             OPT22750
530   FORMAT(/,5X,'****** WARNING *****',5X,'IMPROPER DATA ENTRY   ',/) OPT22760
      END                                                               OPT22770
C====================================================================== OPT22780
C====================================================================== OPT22790
      SUBROUTINE RLINE(ILN)                                             OPT22800
C  SUBROUTINE TO READ IN A STRING OF CHARACTERS OR LINE.  IF THE USER   OPT22810
C  INADVERTENTLY ENTERS A NULL STRING, THE S/R ISSUES A WARNING AND     OPT22820
C  ALLOWS A RECOVERY.  TWO NULL STRINGS & YOU ARE OUT                   OPT22830
C====================================================================== OPT22840
      INTEGER ILN,LINES,BLANK,COUNT,I,LINE                              OPT22850
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT22860
C---------------------------------------------------------------------- OPT22870
      DATA BLANK/'    '/                                                OPT22880
      DO 5 I=1,18                                                       OPT22890
         LINES(ILN,I)=BLANK                                             OPT22900
5     CONTINUE                                                          OPT22910
      COUNT=0                                                           OPT22920
10    COUNT=COUNT+1                                                     OPT22930
      IF(COUNT.LT.3) GO TO 20                                           OPT22940
         WRITE(6,60)                                                    OPT22950
      GO TO 40                                                          OPT22960
20    CONTINUE                                                          OPT22970
      REWIND 4                                                          OPT22980
      READ(5,70,END=30,ERR=30)(LINES(ILN,J),J=1,9)                      OPT22990
      RETURN                                                            OPT23000
30    REWIND 4                                                          OPT23010
      WRITE(6,50)                                                       OPT23020
      GO TO 10                                                          OPT23030
40    CONTINUE                                                          OPT23040
```

```
      STOP                                                              OPT23050
C-----------------------------------------------------------------------OPT23060
50    FORMAT(1X,'WARNING: NULL STRINGS ARE NOT ALLOWED, ENTER',         OPT23070
     *1X,'CHARACTER VALUES.')                                           OPT23080
60    FORMAT(////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)   OPT23090
70    FORMAT(9A4)                                                       OPT23100
      END                                                               OPT23110
C=======================================================================OPT23120
C=======================================================================OPT23130
      SUBROUTINE CLINE(ILN)                                             OPT23140
C  SUBROUTINE PLACES A DOLLAR SIGN AT THE END OF A CHARACTER STING      OPT23150
C  ENTERED FROM THE KEYBOARD AND PLACES THE RESULTING STRING INTO       OPT23160
C  A 1-D ARRAY TO BE USED BY DISSPLA                                    OPT23170
C=======================================================================OPT23180
      INTEGER I,ILN,LINES,J,LINE,DOLLAR,BLANK                           OPT23190
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT23200
C-----------------------------------------------------------------------OPT23210
      DATA DOLLAR/'$   '/,BLANK/'    '/                                 OPT23220
      DO 10 I=1,9                                                       OPT23230
         J=I                                                            OPT23240
         LINE(I)=LINES(ILN,I)                                           OPT23250
         IF(LINE(I).EQ.BLANK) GO TO 20                                  OPT23260
10    CONTINUE                                                          OPT23270
20    LINE(J)=DOLLAR                                                    OPT23280
      RETURN                                                            OPT23290
      END                                                               OPT23300
C=======================================================================OPT23310
C=======================================================================OPT23320
C  SUBROUTINE RDREAL -- INTERACTIVELY READS A REAL NUMBER REPLY        =OPT23330
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL    =OPT23340
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.              =OPT23350
C=======================================================================OPT23360
      SUBROUTINE RDREAL (ANSR)                                          OPT23370
      REAL*8 ANSR                                                       OPT23380
      INTEGER COUNT                                                     OPT23390
C-----------------------------------------------------------------------OPT23400
      COUNT=0                                                           OPT23410
10    CONTINUE                                                          OPT23420
      COUNT=COUNT+1                                                     OPT23430
      IF (COUNT.LT.3) GO TO 20                                          OPT23440
      WRITE (6,60)                                                      OPT23450
      GO TO 40                                                          OPT23460
20    CONTINUE                                                          OPT23470
      READ (5,*,END=30,ERR=30) ANSR                                     OPT23480
      RETURN                                                            OPT23490
30    REWIND 5                                                          OPT23500
      WRITE (6,50)                                                      OPT23510
      GO TO 10                                                          OPT23520
```

```
40    CONTINUE
      STOP
C-----------------------------------------------------------------------
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUME
     1RICAL VALUE.)
60    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)
      END
C=======================================================================
C=======================================================================
C  SUBROUTINE RDINT -- INTERACTIVELY READS AN INTEGER REPLY            =
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL    =
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.              =
C=======================================================================
      SUBROUTINE RDINT (IANS)
      INTEGER COUNT,IANS
C-----------------------------------------------------------------------
      COUNT=0
10    CONTINUE
      COUNT=COUNT+1
      IF (COUNT.LT.3) GO TO 20
      WRITE (6,60)
      GO TO 40
20    CONTINUE
      READ (5,*,END=30,ERR=30) IANS
      RETURN
30    REWIND 5
      WRITE (6,50)
      GO TO 10
40    CONTINUE
      STOP
C-----------------------------------------------------------------------
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUME
     1RICAL VALUE.)
60    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)
      END
C=======================================================================
C=======================================================================
C  SUBROUTINE RDCHAR -- INTERACTIVELY READS A CHARACTER STRING REPLY   =
C  ('YES' OR 'NO') INTO A FORTRAN PROGRAM. IF THE USER INADVERTENLY    =
C  ENTERS  A NULL STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY=
C=======================================================================
      SUBROUTINE RDCHAR (IANS)
      INTEGER COUNT,IANS
C-----------------------------------------------------------------------
      COUNT=0
10    CONTINUE
      COUNT=COUNT+1
      IF (COUNT.LT.3) GO TO 20
      WRITE (6,6C)                                                      OPT24010
      GO TO 40                                                          OPT24020
2C    CCNTINUE                                                          OPT24030
      REWIND 5                                                          OPT24040
      READ (5,70,END=30,ERR=30) IANS                                    OPT24050
      RETURN                                                            OPT24060
3C    REWIND 5                                                          OPT24070
      WRITE (6,5C)                                                      OPT24080
      GC TO 10                                                          OPT24090
4C    CCNTINUE                                                          OPT24100
      STOP                                                              OPT24110
C-----------------------------------------------------------------------OPT24120
5C    FCRMAT (1X,60HWARNING:  NULL STRINGS ARE NCT ALLCWED, ENTER "YES" OPT24130
     1CR "NO".)                                                         OPT24140
6C    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)  OPT24150
7C    FCRMAT (A1)                                                       OPT24160
      END                                                               OPT24170
C=======================================================================OPT24180
C=======================================================================OPT24190
      SLBROUTINE MINMAX(N,AA,MIN,MAX)                                   OPT24200
C     SUBROUTINE MINMAX FINDS THE MINIMUM AND MAXIMUM VALUES FOR A CNE  OPT24210
C     CIMENSIONAL ARRAY                                                 OPT24220
C=======================================================================OPT24230
      REAL*4 MIN,MAX,AA                                                 OPT24240
      INTEGER N                                                         OPT24250
      DIMENSION AA(N)                                                   OPT24260
C-----------------------------------------------------------------------OPT24270
      MAX = AA(1)                                                       OPT24280
      MIN = AA(1)                                                       OPT24290
      CC 10 I = 1,N                                                     OPT24300
      IF(AA(I).GT.MAX) GC TO 5                                          OPT24310
      IF(AA(I).LT.MIN) GO TO 6                                          OPT24320
      GO TO 10                                                          OPT24330
5     MAX = AA(I)                                                       OPT24340
      GO TO 10                                                          OPT24350
6     MIN = AA(I)                                                       OPT24360
1C    CONTINUE                                                          OPT24370
      FETURN                                                            OPT24380
      END                                                               OPT24390
C=======================================================================OPT24400
C=======================================================================OPT24410
      SLBROUTINE MAKPOL(N,R,C)                                          OPT24420
C     SUBROUTINE MAKPCL COMPUTES THE COMPLEX COEFFICIENTS OF AN N-TH    OPT24430
C     CEGREE PCLYNOMIAL GIVEN N COMPLEX ROOTS OF THE POLYNOMIAL         OPT24440
C=======================================================================OPT24450
      CCMPLEX*16 R(N),C(N)                                              OPT24460
      IF(N.LE.0) RETURN                                                 OPT24470
      CO 10 I=1,N                                                       OPT24480
```

```
   10 C(I)=R(I)                                                         OPT24490
      IF(N.NE.1)GO TO 15                                                OPT24500
      I=1                                                               OPT24510
      GO TO 40                                                          OPT24520
   15 K=N                                                               OPT24530
      M=N-1                                                             OPT24540
      DO 20 L=1,M                                                       OPT24550
      DO 30 I=2,K                                                       OPT24560
   30 C(I)=C(I)+C(I-1)                                                  OPT24570
      K=K-1                                                             OPT24580
      DO 20 I=1,K                                                       OPT24590
      J=I+L                                                             OPT24600
      C(I)=R(J)*C(I)                                                    OPT24610
   20 CONTINUE                                                          OPT24620
      K=N/2                                                             OPT24630
      K=2*K/(N-K)                                                       OPT24640
      DO 40 I=K,N,2                                                     OPT24650
   40 C(I)=-C(I)                                                        OPT24660
      RETURN                                                            OPT24670
C-----------------------------------------------------------------------OPT24680
      END                                                               OPT24690
C=======================================================================OPT24700
C=======================================================================OPT24710
      SUBROUTINE PRTPLT(IPP)                                            OPT24720
C     SUBROUTINE PRTPLT INTERACTIVELY ALLOWS THE USER TO SELECT EITHER  OPT24730
C     GRAPHICAL OUTPUT, TABULAR DATA, OR TO QUIT.                       OPT24740
C=======================================================================OPT24750
      INTEGER IPTR,IANS                                                 OPT24760
C-----------------------------------------------------------------------OPT24770
      WRITE(6,100)                                                      OPT24780
30    WRITE(6,110)                                                      OPT24790
      CALL RDINT(IANS)                                                  OPT24800
      IF(IANS.GT.3.OR.IANS.LT.1) GO TO 15                               OPT24810
      GO TO 25                                                          OPT24820
15    WRITE(6,510)                                                      OPT24830
      GO TO 30                                                          OPT24840
25    CONTINUE                                                          OPT24850
      IPP = IANS                                                        OPT24860
C-----------------------------------------------------------------------OPT24870
      RETURN                                                            OPT24880
C-----------------------------------------------------------------------OPT24890
100   FORMAT(//,5X,'DO YOU DESIRE:',//,                                 OPT24900
     *10X,'1.  GRAPHICAL OUTPUT',/,                                     OPT24910
     *10X,'2.  TABULAR DATA',/,                                         OPT24920
     *10X,'3.  QUIT SUBROUTINE',/)                                      OPT24930
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                             OPT24940
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)    OPT24950
C-----------------------------------------------------------------------OPT24960
```

```
      END                                                               OPT24970
C=======================================================================OPT24980
C=======================================================================OPT24990
      SUBROUTINE FRTR(IPT)                                              OPT25000
C     SUBROUTINE FRTR INTERACTIVELY ALLOWS THE USER TO SELECT THE       OPT25010
C     THE OUTPUT DEVICE FOR TABULAR DATA.                               OPT25020
C=======================================================================OPT25030
      INTEGER IPT,IANS                                                  OPT25040
C-----------------------------------------------------------------------OPT25050
      WRITE(6,100)                                                      OPT25060
30    WRITE(6,110)                                                      OPT25070
      CALL RDINT(IANS)                                                  OPT25080
      IF(IANS.GT.3.OR.IANS.LT.1) GO TO 15                               OPT25090
      GO TO 25                                                          OPT25100
15    WRITE(6,510)                                                      OPT25110
      GO TO 30                                                          OPT25120
25    CONTINUE                                                          OPT25130
      GO TO (40,50,60),IANS                                             OPT25140
40    IPT = 6                                                           OPT25150
      GO TO 80                                                          OPT25160
50    IPT = 3                                                           OPT25170
      GO TO 80                                                          OPT25180
60    IPT = 2                                                           OPT25190
      GO TO 80                                                          OPT25200
C-----------------------------------------------------------------------OPT25210
80    RETURN                                                            OPT25220
C-----------------------------------------------------------------------OPT25230
100   FORMAT(//,5X,'DO YOU DESIRE TABULAR OUTPUT TO GO TO:',//,         OPT25240
     *10X,'1.  SCREEN',/,                                               OPT25250
     *10X,'2.  PRINTER',/,                                              OPT25260
     *10X,'3.  DISK (OPGRAPH LISTING)',/)                               OPT25270
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                             OPT25280
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)    OPT25290
C-----------------------------------------------------------------------OPT25300
      END                                                               OPT25310
C=======================================================================OPT25320
C=======================================================================OPT25330
      SUBROUTINE NPTS(PTS)                                              OPT25340
C     SUBROUTINE NPTS INTERACTIVELY ALLOWS THE USER TO SELECT THE NUMBEROPT25350
C     OF POINTS TO BE CALCULATED FOR TABULAR DATA                       OPT25360
C=======================================================================OPT25370
      INTEGER PTS,IANS                                                  OPT25380
C-----------------------------------------------------------------------OPT25390
      WRITE(6,100)                                                      OPT25400
30    WRITE(6,110)                                                      OPT25410
      CALL RDINT(IANS)                                                  OPT25420
      IF(IANS.GT.500.OR.IANS.LT.1) GO TO 15                             OPT25430
      GO TO 25                                                          OPT25440
```

```
15    WRITE(6,510)                                                       OPT25450
      GC TO 30                                                           OPT25460
25    CCNTINUE                                                           OPT25470
      PTS = IANS                                                         OPT25480
C-----------------------------------------------------------------------OPT25490
      RETURN                                                             OPT25500
C-----------------------------------------------------------------------OPT25510
1C0   FORMAT(//,5X,'HOW MANY POINTS DO YOU WANT TC TABULATE?',/,         OPT25520
     *10X,'(500 IS THE MAXIMUM)',/)                                      OPT25530
110   FORMAT(/,5X,'ENTER NUMBER OF POINTS.',/)                           OPT25540
510   FORMAT(/,5X,'****** ERROR ******',10X,'MUST ENTER BETWEEN 1 AND 50OPT25550
     *0 POINTS   ',/)                                                    OPT25560
C-----------------------------------------------------------------------OPT25570
      END                                                                OPT25580
C=======================================================================OPT25590
C=======================================================================OPT25600
      SLBROUTINE PSCALE(PAGEX)                                           OPT25610
C     SUBROUTINE PSCALE AUTOMATICALLY SCALES DISSPLA PLCTS               OPT25620
C=======================================================================OPT25630
      REAL*4 PAGEX,TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10              OPT25640
      CCMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10            OPT25650
C-----------------------------------------------------------------------OPT25660
      TS = PAGEX/11.0                                                    OPT25670
      TH = 0.14*TS                                                       OPT25680
      TH1 = 0.10*TS                                                      OPT25690
      T1 = 0.60*TS                                                       OPT25700
      T2 = 1.60*TS                                                       OPT25710
      T3 = 1.20                                                          OPT25720
      T4 = 0.30*TS                                                       OPT25730
      T5 = 2.10*TS                                                       OPT25740
      T6 = 0.9 *TS                                                       OPT25750
      T7 = 2.00*TS                                                       OPT25760
      T8 = 0.20*TS                                                       OPT25770
      T9 = 2.0*TS                                                        OPT25780
      T10 = 3.0*TS                                                       OPT25790
      IF(PAGEX.LT.6.0) T3 =1.0                                           OPT25800
      RETURN                                                             OPT25810
C-----------------------------------------------------------------------OPT25820
      END                                                                OPT25830
```

APPENDIX D

OPGRAPH LISTING

This portion of the thesis contains a sample of tatular output sent to a disk (OPGRAPH LISTING)

```
           BODE PLOT
COMPENSATOR TRANSFER FUNCTION


     INPUT NUMBER =            1
     OUTPUT NUMBER =           1
     DENOMINATOR ORDER =       2
     NUMERATOR ORDER =         1
     TRANSFER FUNCTION (DC) GAIN = -0.1135D+06

   FREQUENCY        MAGNITUDE        PHASE            REAL             IMAGINARY
   (RAD/SEC)        (DECIBELS)       (DEGREES)         PART             PART
   0.1000D+02       0.4815D+02       -0.1482D+03      -0.2171D+03      -0.1346D+03
   0.1778D+02       0.5106D+02       -0.1401D+03      -0.2740D+03      -0.2292D+03
   0.3162D+02       0.5504D+02       -0.1423D+03      -0.4466D+03      -0.3456D+03
   0.5623D+02       0.5891D+02       -0.1629D+03      -0.8431D+03      -0.2598D+03
   0.1000D+03       0.5956D+02       -0.2025D+03      -0.8786D+03       0.3637D+03
```

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